Instruction Manual AVTM672000

for

Automatic Balance
Capacitance and Dissipation Factor
Test Set
Catalog Number 672000 and 672000-R

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Electro Rent Corporation

AVO INTERNATIONAL
The Measure of Excellence in Electrical Testing

Instruction Manual AVTM672000

for

Automatic Balance
Capacitance and Dissipation Factor
Test Set
Catalog Number 672000 and 672000-R

High-Voltage Equipment
Read the entire manual before operating.

Aparato de Alto Voltaje
Antes de operar este producto lea este manual enteramente.

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Section 1

Introduction

RECEIVING INSTRUCTIONS

Check the equipment received against the packing list to ensure that all materials are present. Notify AVO International of any shortage. Telephone (215) 646-9200.

Examine the instrument for damage received in transit. If damage is discovered, file a claim with the carrier at once and notify AVO International, giving a detailed description of the damage.

This instrument has been thoroughly tested and inspected to meet rigid specifications before being shipped. It is ready for use when set up as indicated in this manual.

GENERAL INFORMATION

The Automatic Balance Capacitance and Dissipation Factor Test Set is used for shop and field testing of high-voltage electrical insulating systems at test voltages up to 12 kV. The results of the test set can be used to evaluate the nature and quality of electrical insulation materials and manufacturing processes and reveals contamination, fractures, punctures, and other defects which accompany the aging of insulation. The test set comprises a control unit, a high-voltage unit, cables, and canvas carrying bags. See Figure 1.

Tests are made by measuring the capacitance and dissipation factor (power factor) of a specimen. The values measured will change when undesirable conditions exist, such as moisture on or in the insulation; shorts or opens in windings or insulation; the presence of conductive contaminants in insulating oil, gas or solids; and the presence of internal partial discharges.

The test set measures the capacitance and dissipation factor of electrical insulation on high-voltage power equipment such as cables, bushings, insulators, circuit breakers, transformers, rotating machines, capacitors, and surge (lightning) arresters.

The test set measures changes of capacitance and dielectric loss due to variations of voltage level and ambient conditions, e.g., changes in temperature, humidity, pressure, mechanical shock, vibration, and stress. Dielectric constant and transformer excitation current can also be measured.

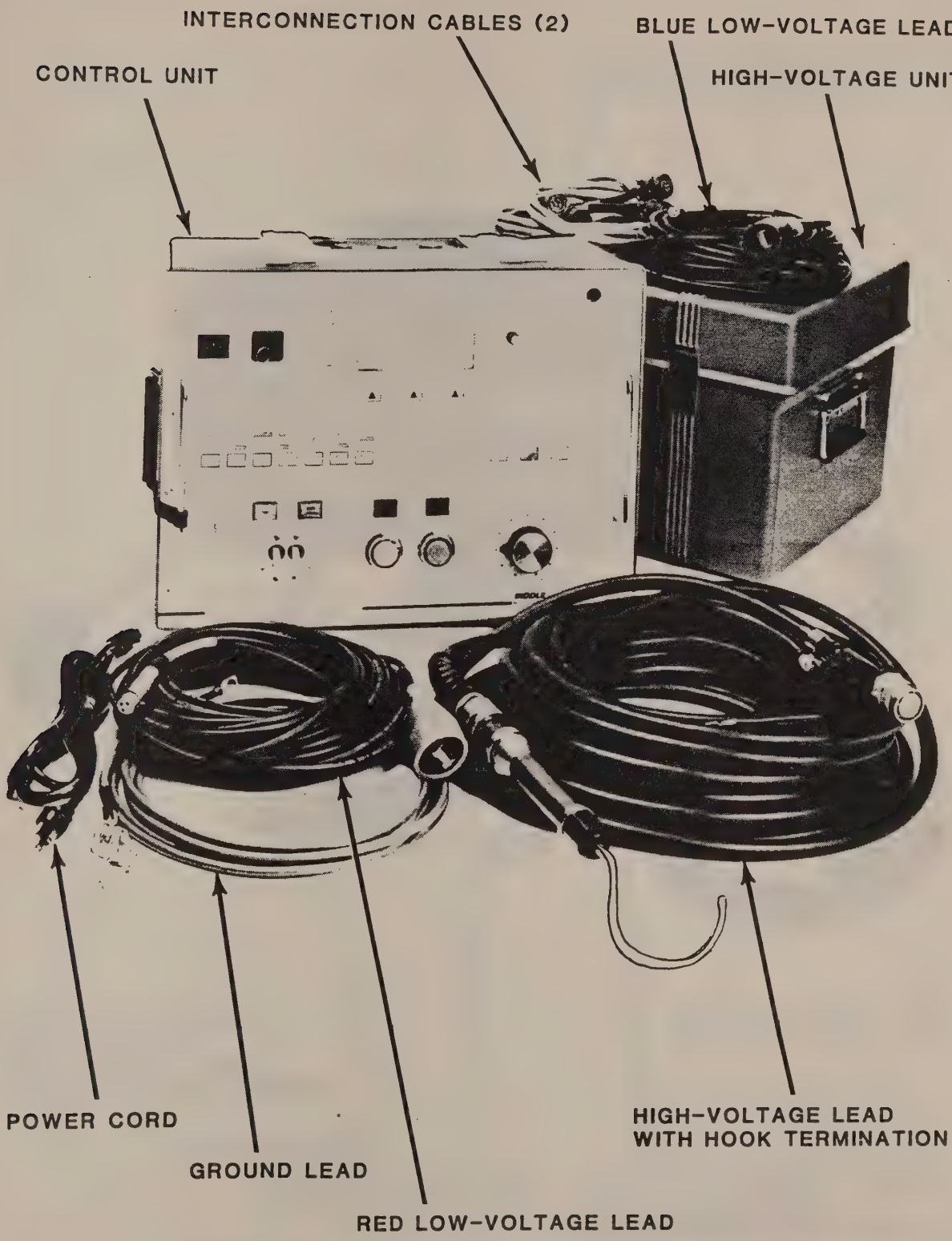


Figure 1: Test Set and Accessories

Figure 1: Test Set and Accessories (contd)

The test set makes all UST and GST tests on high-voltage apparatus; seven front-panel TEST MODE switches set up test configuration.

- Ungrounded specimen test (UST), three positions
- Grounded specimen test (GST), one position
- Grounded specimen test using guard connection (GSTg), three positions

Features include:

- Automatic balance control by high-performance microprocessor.
- Automatic self-checking of test set calibration and operation.
- Large, easy-to-read LCD shows alphanumeric and graphic data.
- Front-panel MENU switches select operating mode.
- Dual low-voltage output cables simplify measurements on multi-winding transformers and circuit breakers containing inboard and outboard bushings.
- Automatic interference suppression circuit ensures trouble-free operation in switchyards (up to 765 kV) under electrostatic and magnetic interference conditions. The interference suppressor circuit may be turned on and off using MENU switches. When the interference suppressor circuit is turned on, the level of interference is shown on the display.
- Direct reading of the following information:

  Voltage
  Current
  Current at 10 kV
  Percent Dissipation Factor
  Percent Power Factor
  Watts at 10 kV

- External printer records test data.
- Bar code reader records equipment identification.
- Data key stores 127 tests for retrieval and analysis. Stored data can be transferred to a personal computer (PC).

Section 2

Safety

The test set and the specimen to which it is connected are a possible source of high voltage electrical energy and all persons making or assisting in tests must use all practical safety precautions to prevent contact with energized parts of the test equipment and related circuits. Persons actually engaged in the test must stand clear of all parts of the complete high-voltage circuit, including all connections, unless the test set is de-energized and all parts of the test circuit are grounded. Persons not directly involved with the work must be kept away from test activities by suitable barriers, barricades, or warnings. An interlock circuit is provided on the control unit of the test set to enable the operator to enclose all parts of the complete high-voltage circuit within a secure area. The interlock circuit should be used to shut off input power automatically upon unauthorized entry into the high-voltage area.

Treat all terminals of high-voltage power equipment as a potential electric shock hazard. There is always the potential of voltages being induced at these terminals because of proximity to energized high-voltage lines or equipment. Always use a safety ground stick to ground the high-voltage conductor. A safety ground jumper must then be installed between all terminals of apparatus under test and ground. Always disconnect test leads from power equipment before attempting to disconnect them at the test set. The ground connection must be the first made and the last removed. Any interruption of the grounding connection can create an electric shock hazard.

This instrument operates from a single-phase power source. It has a three-wire power cord and requires a two-pole, three-terminal, live, neutral, and ground type connector. The voltage to ground from the live pole of the power source must not exceed the maximum rated operating voltage:

120 V, 60 Hz for Cat. No. 672000 (-R)
120 V, 50 Hz for Cat. No. 672000 (-R)-44
250 V, 60 Hz for Cat. No. 672000 (-R)-47
250 V, 50 Hz for Cat. No. 672000 (-R)-45

The neutral pole must be at ground potential. Before making connection to the power source, determine that the instrument rating matches the voltage of the power source and has a suitable two-pole, three-terminal grounding connector.

The power input plug must be inserted only into a mating receptacle with a ground contact. Do not bypass the grounding connection. Any interruption of the grounding connection can create an electric shock hazard. Determine that the receptacle is properly wired

before inserting the plug.

Test sets energized with 220/240 V input voltage are energized via an internal autotransformer which is used for voltage reduction. The neutral terminal of the input supply cord (white or blue lead) must be connected to the neutral pole of the line power source. The ground terminal of the input supply cord (green or yellow/green lead) must be connected to the protective ground (earth) terminal of the line power source. The black or brown cord lead is the live (hot) lead. These test sets must not be energized from a power source where both poles are live. These test sets are protected by a fuse. Refer fuse replacement to qualified personnel only. To avoid electric shock and fire hazard, use only the fuse specified in Section 3, Specifications, which is identical in respect to type, voltage rating, and current rating.

AVO International has made formal safety reviews of the initial design and any subsequent changes. This procedure is followed for all new Biddle Products and covers areas in addition to those included in applicable standards. Regardless of these efforts, it is not possible to eliminate all hazards from electrical test equipment. For this reason, every effort has been made to point out in this instruction manual the proper procedures and precautions to be followed by the user in operating this equipment and to mark the equipment itself with precautionary warnings where appropriate. It is not possible to foresee every hazard which may occur in the various applications of this equipment. It is therefore essential that the USER, in addition to following the safety rules in this manual, also carefully consider all safety aspects of the test before proceeding.

- Safety is the responsibility of the user.
- Misuse of this high-voltage equipment can be extremely dangerous.
- The purpose of this equipment is limited to use as described in this manual. Do not use the equipment or its accessories with any device other than specifically described.
- Never connect the test set to energized equipment.
- Operation is prohibited in rain or snow.
- Do not use the test set in an explosive atmosphere.
- A qualified operator should be in attendance at all times while the test equipment is in operation.
- Observe all safety warnings marked on the equipment.
- Corrective maintenance must only be performed by qualified

personnel who are familiar with the construction and operation of the test set and the hazards involved.

- Refer to IEEE 510 - 1983, "IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing," for information.

If the test equipment is operated properly and all grounds correctly made, test personnel need not wear rubber gloves. As a routine safety procedure, however, some users require that rubber gloves be worn, not only when making connections to the high-voltage terminals, but also when manipulating the controls. AVO International considers this an excellent safety practice.

High-voltage discharges and other sources of strong electric or magnetic fields may interfere with the proper functioning of heart pacemakers. Persons with heart pacemakers should obtain expert advice on the possible risks before operating this equipment or being close to the equipment during operation.

The following warning and caution notices are used throughout this manual where applicable and should be strictly observed.

WARNING

Warning, as used in this manual, is defined as a condition or practice which could result in personal injury or loss of life.

CAUTION

Caution, as used in this manual, is defined as a condition or practice which could result in damage to or destruction of the equipment or apparatus under test.

Section 3

Specifications

ELECTRICAL

Input Power

Cat. No. 672000 and 672000-44:
120 V, 60,50 Hz, 10 A continuous; IEC 1010-1 installation category II

Cat. No. 672000-45 and 672000-47:
240 V, 60,50 Hz, 5 A continuous; IEC 1010-1 installation category II

1 kVA continuous

Protective Devices

Circuit breaker, all models:	10 A
Fuse, 220/240 V models only:	15 A, 250 V, time delay IEC designation T (Buss designation MDA, ceramic)

Output Voltage and Current

Output voltage range:	0 to 12 kV
Maximum continuous current:	100 mA @ 10 kV
Maximum current:	200 mA @ 10 kV, 10 min on, 60 min off

Test Frequency

50 or 60 Hz

Measuring Ranges

Voltage: 0 to 12 kV, 0.01 kV resolution
minimum recommended operating voltage is 0.5 kV

Current: 0 to 200 mA, 1 µA maximum resolution
Also measures 10 kV equivalent current

Capacitance: 1 pF to 0.111 µF, 0.01 pF maximum resolution

Dissipation Factor: 0 to 200%, 0.01% DF maximum resolution

Power Factor: 0 to 90%, 0.01% PF maximum resolution

Watts-Loss at 10 kV: 0 to 8.5 kW, maximum resolution 0.1 mW

Test set also can measure negative values of DF, PF and Watts-Loss.

Accuracy

Voltage (rms): ±(1% of reading + 1 digit)
Current (rms): ±(1% of reading + 1 digit)
Capacitance: ±(0.5% of reading + 2 pF) UST
±(0.5% of reading + 6 pF) GST
Dissipation Factor: ±(2% of reading + 0.05% DF)
Power Factor: ±(2% of reading + 0.05% PF)
Watt-Loss at 10 kV: ±(2% of reading + 1 mW)

Measuring Time

10 to 45 seconds, nominally

Test Modes

Seven test modes to make all UST and GST tests.

Operating Modes

The following operating modes may be selected by front panel MENU switches. Status of selections is indicated continuously on the graphic display.

1. Measurements of capacitance or transformer excitation current.

2. Measurements with normal and reverse, or normal only voltage polarity.

3. Measurements with interference suppressor turned on or off.

4. Selection of PRINT/STORE, PRINT ONLY, STORE ONLY or NONE for handling of measurements data.

5. Selection of UNLOCK or LOCK operating modes. Lock mode is used to set up single operating condition.

Interference Suppression

Automatic suppression for the interference currents present in high-voltage switchyards. Measurements can be made with or without interference suppression. Level of interference current measured and displayed.

Bridge Circuit

Based on principle of opposing ampere-turn balance using adjustable transformer ratio arms.

Reference Capacitor

Fixed gas capacitor (fully shielded): 100 pF ±0.5%, 12 kV.

Power Transformer

Double-shielded construction.

Guarding

Cold guard type circuit. Guard circuit encloses power transformer, reference capacitor, entire high-voltage circuit and output test cables.

Printer

A battery-powered printer is supplied to print test results of the present test or test result readings stored on the data key. The printer supplied is Thermal Printer DPU-411 Type II by Seiko Instruments Inc. A separate manual is supplied with the printer.

Bar Code Wand

The equipment ID No. can be included in the test results using the bar code wand supplied. The wand reads bar code labels up to 19 characters long using Code 39. A printed form is supplied that has all the individual characters for entry. Entry can be made by individual character or by entire ID No. from a bar code label. Refer to Appendix A for a description of the bar code generator program.

Data Keys

Two data keys are provided; each stores 127 test results. Data can be transferred to a PC using the interface box and PC program supplied. Refer to Appendix B for a description of the data-key data downloader program.

Maximum Specimen Capacitance Measurable at 50/60 Hz

Test Volts (kV)	Maximum Capacitance (μF) (100 mA continuous service)		Maximum Capacitance (μF) (200 mA for 10 minutes)	
	60 Hz	50 Hz	60 Hz	50 Hz
2.5 & less	0.11	0.11	0.11	0.11
4.0	0.066	0.080	0.11	0.11
5.0	0.052	0.062	0.11	0.11
6.0	0.044	0.053	0.088	0.106
8.0	0.033	0.040	0.066	0.080
10.0	0.026	0.031	0.052	0.062
12.0	0.022	0.026	0.044	0.053

Terminals

High-voltage
Low-voltage (2) marked red and blue
Interconnection (2)
Supply power
External interlock
Ground
Printer
Bar code reader
Data key

SAFETY FEATURES

- Zero start for output voltage.
- An external hand interlock switch (supplied) must be closed to energize high-voltage circuit.
- Double ground required to energize high voltage circuit.
- Circuit breaker for short-circuit protection.
- All controls at ground potential.
- Overvoltage protective devices prevent damage to test set in the event of specimen breakdown.

ENVIRONMENTAL

Operating temperature range:	-4 to 122°F (-20 to 50°C)
Storage temperature range:	-58 to 140°F (-50 to 60°C)
Relative humidity:	0 to 90% noncondensing (operating)
	0 to 95% noncondensing (storage)

CAUTION

Storage for extended periods of time at high temperature and relative humidity may cause degradation of the LCD.

PHYSICAL DATA

General

Test set consists of two separate units: control unit and high-voltage unit.*

Cases are bronze color polycarbonate structural foam with heavy-duty carrying handles.

Two black canvas bags are provided to carry test cables.*

* Not included with Catalog No. 672000-R.

Dimensions

Control unit: 19.5 x 15 x 12.5 in. (L x W x H) (51 x 38 x 31 cm)
High-voltage unit*: 19.5 x 15 x 12.5 in. (L x W x H) (51 x 38 x 31 cm)
Cable bag*: 15 x 17 x 4 in. (W x H x D) (38 x 43 x 10 cm)

Weight

Control unit (120 V operation):	52 lb (24 kg)
Control unit (240 V operation):	67 lb (31 kg)
High-voltage unit*:	63 lb (29 kg)
Cables (in bags)*:	35 lb (16 kg)

ACCESSORIES SUPPLIED

Power cord*, 8 ft (2.5 m)
Ground lead*, 15 ft (4.6 m)
High-voltage lead*, 70 ft (21.4 m), double shielded,interchangeable hook or clip terminations
Low-voltage leads*, two 70 ft (21.4 m), shielded, (color coded red and blue)
Control unit to high-voltage unit interconnection cables, two 5 ft (1.5 m)
External interlock control cable, with hand interlock switch, 8 ft (2.5 m)
Two canvas carrying bags for test leads*
Instruction Manual
Battery-powered printer
Bar code wand
Two data keys
Data key RS232C interface box

OPTIONAL ACCESSORIES

Calibration and Dissipation Factor Standard	Cat. No. 670500-1
Oil Test Cell	Cat. No. 670511
Hot-collar belts (3)	Cat. No. 670505
Bushing tap connectors (2)	Cat. No. 670506
Transit case for test set (2)	Cat. No. 670626
Transit case for cables	Cat. No. 218744-1
Transit case for standard	Cat. No. 670635

* Not included with Catalog No. 672000-R.

Section 4

Controls, Indicators, and Connectors

CONTROL UNIT FRONT PANEL (Fig.2)

1. Ground terminal - this wing nut allows connection of test set to earth ground.

2. Input power receptacle - allows connection of test set to ac power source as marked on panel.

3. TEST MODE - seven membrane-type switches select the UST-GST operating mode. Color bars above switch positions identify connection of test leads as to measurement, guarding or grounding.

   UST 1 — Ungrounded specimen test, measures high to red low and high to blue low leads.

   UST 2 — Ungrounded specimen test, measures high to blue low lead.

   UST 3 — Ungrounded specimen test, measures high to red low lead.

   GST 4 — Grounded specimen test, measures high to red low and high to blue low leads plus high to ground.

   GSTg 5 — Grounded specimen test, measures high to ground. Red and blue leads guarded.

   GSTg 6 — Grounded specimen test, measures high to red low lead and high to ground. Blue lead guarded.

   GSTg 7 — Grounded specimen test, measures high to blue low lead and high to ground. Red lead guarded.

4. Data key receptacle - provides capability to store test results when a data key is inserted. One data key stores 127 test results. Two data keys are supplied. Data can then be transferred to a PC using the data key RS232C interface box.

5. mA, mA @ 10 kV - membrane-type switch used to select current readout of mA or mA @ 10 kV in graphic display.

6. % DF, % PF, W @ 10 kV - membrane type switch used to select insulation loss readout in terms of % DF, % PF, or W @ 10 kV.

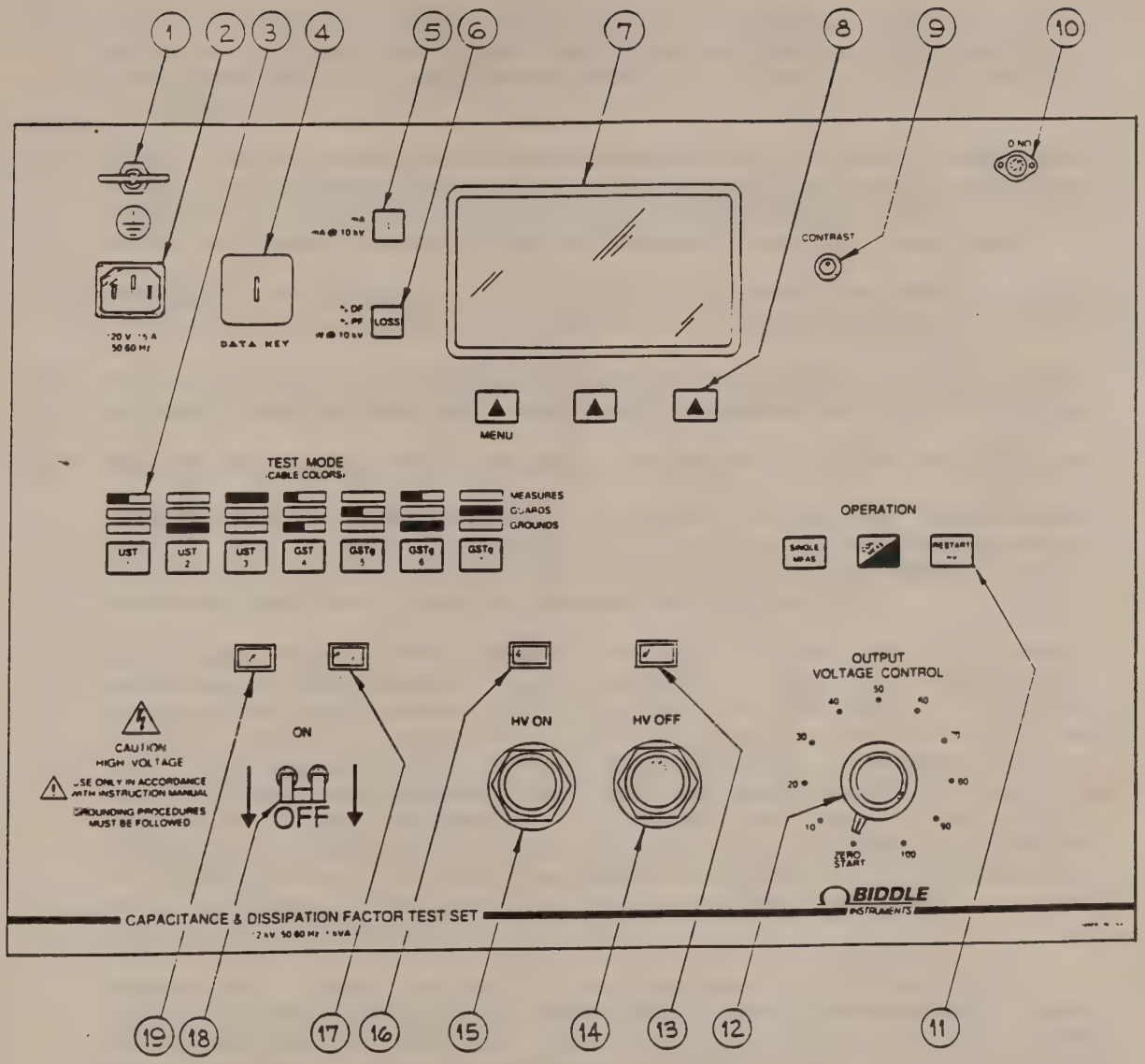


Figure 2: Control Unit Front Panel

7. LCD - graphic display guides the operator through menu-selected setup, test, and calibration procedures; displays test results and indicates status of setup and operating procedures.

8. MENU - three membrane-type switches select main menu, move cursor up or down, select setup for operation mode, send test results to printer port, store test results in data key, and enter equipment identification number from bar code wand.

9. CONTRAST - this control changes the contrast and viewing angle of the LCD when turned clockwise or counterclockwise.

10. ID NO. - allows equipment identification number to be included in test results when bar code wand is connected to receptacle.

11. OPERATION - three membrane-type switches function as follows:

    SINGLE MEAS - when pressed, initiates a single measurement test. The word SINGLE appears at the bottom right corner of the display. When completed, test voltage is removed from the specimen and test results indicated in the LCD.

    CONT MEAS/STOP - when pressed the first time, it initiates a continuous measurement test routine. The word CONTINUOUS appears at the bottom right corner of the LCD. When the initial test is completed, the test results are shown in the LCD. The measurement is then continuously repeated and the display readings updated each time the measurement sequence is completed. When the switch is pressed the second time, STOP, (for several seconds) the test routine changes from CONTINUOUS to SINGLE test. At the completion of the last measurement, test voltage is removed from the specimen and the last test results are indicated in the LCD.

    RESTART HV - this switch is only active after the final results from a single or continuous (stop) measurement test are indicated in the LCD. When pressed, high-voltage can be reapplied to the test specimen without a zero restart of the high-voltage circuit. This time-saving feature allows the operator to repeat tests or make tests using a different TEST MODE switch setting (3) without readjustment of the output voltage setting.

12. OUTPUT VOLTAGE CONTROL - variable-ratio autotransformer adjusts output voltage by controlling primary voltage of high-voltage transformer. This control must be set to ZERO START to activate high-voltage output.

13. TESTING - this red lamp, when lit, indicates that test voltage is being applied to test specimen and a single or continuous measurement test is being performed.

14. HV OFF - this red push-button switch, when pressed, immediately de-energizes high-voltage output. It may be used as an emergency stop. It turns off the red TESTING and red HIGH VOLTAGE lamps and clears display test results.

15. HV ON - this white push-button switch, when pressed, energizes the high-voltage output circuit and red HIGH VOLTAGE lamp when the OUTPUT VOLTAGE CONTROL is set to ZERO START and the external interlock switch closed.

16. HIGH VOLTAGE - this red lamp when lit indicates that the high-voltage output circuit is enabled.

17. OPEN GROUND - this amber lamp when lit indicates an open in double ground system or defective grounding of test set.

18. ON/OFF main circuit breaker - two-pole magnetic circuit breaker controls power to test set and provides short-circuit and overload protection.

19. POWER - this white lamp when lit indicates that the main circuit breaker is set to ON and the test set is energized.

Internal beeper (not shown) - beeps to confirm that a membrane switch has been pressed.

CONTROL UNIT CONNECTOR PANEL (Fig. 3)

20, 21. INTERCONNECTION - these two plug receptacles are for connection of control unit to high-voltage unit.

22. PRINTER - plug receptacle for connection of a printer.

23. INTLK - plug receptacle for connection of external interlock switch.

A hand interlock switch is supplied; however, in the event that the hand interlock is replaced with a test area interlock, the system must be constructed so that the interlock switches are closed when the test area gate or gates are closed. The interlock wiring must be run as a twisted pair to minimize electromagnetic coupling into the system. This interlock system should be wired such that connection is made to A and B sockets of the INTLK receptacle. When the interlock loop is opened the test is automatically terminated.

WARNING

When the external interlock circuit is open and the HV ON switch is pressed, the complete interlock circuit is energized at 120 V. The interlock circuit wiring must be insulated for 120 V.

24. RED LV - plug receptacle for connection of red low-voltage test cable. Used for single low-voltage cable applications.

25. BLUE LV - plug receptacle for connection of blue low-voltage test cable.

HIGH-VOLTAGE UNIT CONNECTOR PANEL (Fig. 4)

26, 27. INTERCONNECTION - these two unmarked plug receptacles are for connection of control unit to high-voltage unit.

28. Plug receptacle for connection of high-voltage output cable.

29. Binding post terminal for connection of ground pigtail lead of high-voltage output cable.

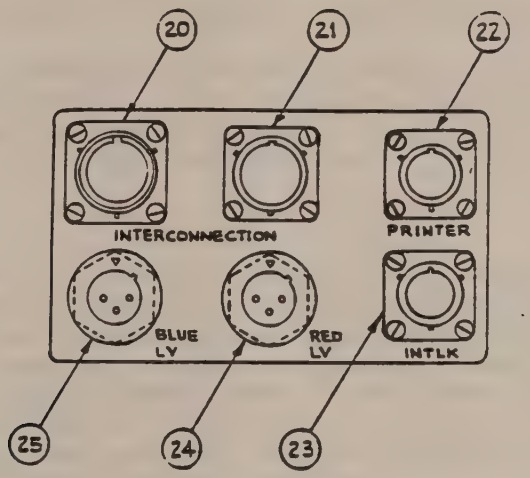


Figure 3: Control Unit Connector Panel

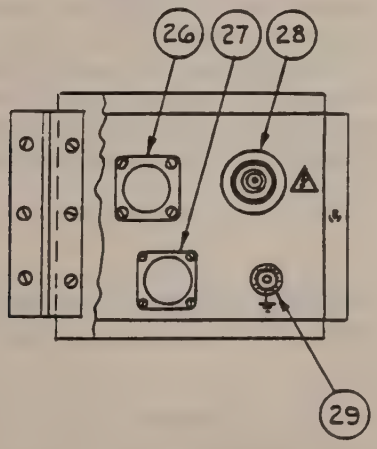


Figure 4: High-Voltage Unit Connector Panel

Section 5

Setup and Operation

SAFETY PRECAUTIONS

The output of this test set can be lethal. As with any high-voltage equipment, caution must be used at all times and all safety procedures followed. Read and understand Section 2, Safety, before proceeding. Be sure that the test specimen is de-energized and grounded before making connections. Clear power equipment to be tested and attach necessary ground to floating bus bars in accordance with standard company policy, observing all safety procedures. Make certain that no one can come in contact with the high-voltage output terminal or any material energized by the output. Use protective barriers if necessary. Locate the control unit and high-voltage unit in an area which is as dry as possible.

Maintain adequate clearances between energized conductors and ground to prevent arc-over. Such accidental arc-over may create a safety hazard or damage the equipment being tested. A minimum clearance of 1 ft (30 cm) is recommended.

SETUP

The following steps are a general guide for setting up the test set. Figure 5 shows a typical setup for testing inter-winding and ground capacitance on a three-phase delta-wye power transformer; Figure 6 shows a typical setup for making excitation current measurements on the same transformer. The test set controls and connectors are identified in Figures 2, 3 and 4. Refer to Section 6, Application Notes, for specific instructions on connecting this and other power equipment to the test set.

WARNING

There is always the possibility of voltages being induced at the terminals of a test specimen because of proximity to energized high-voltage lines or equipment. A residual static voltage charge may also be present at these terminals. Ground each terminal to be tested with a safety ground stick, then install safety ground jumpers, before making connections.

1. Locate the test set at least 6 ft (1.82 m) from the specimen to be tested.

2. Connect the wing thumb-nut ground terminal (1) of the test set to a low impedance earth ground using the 15 ft (4.5 m) ground cable supplied.

3. Connect the control unit receptacle (20, 21) to the high-voltage receptacle (26, 27) using the two 5 ft (1.52 m) interconnection cables.

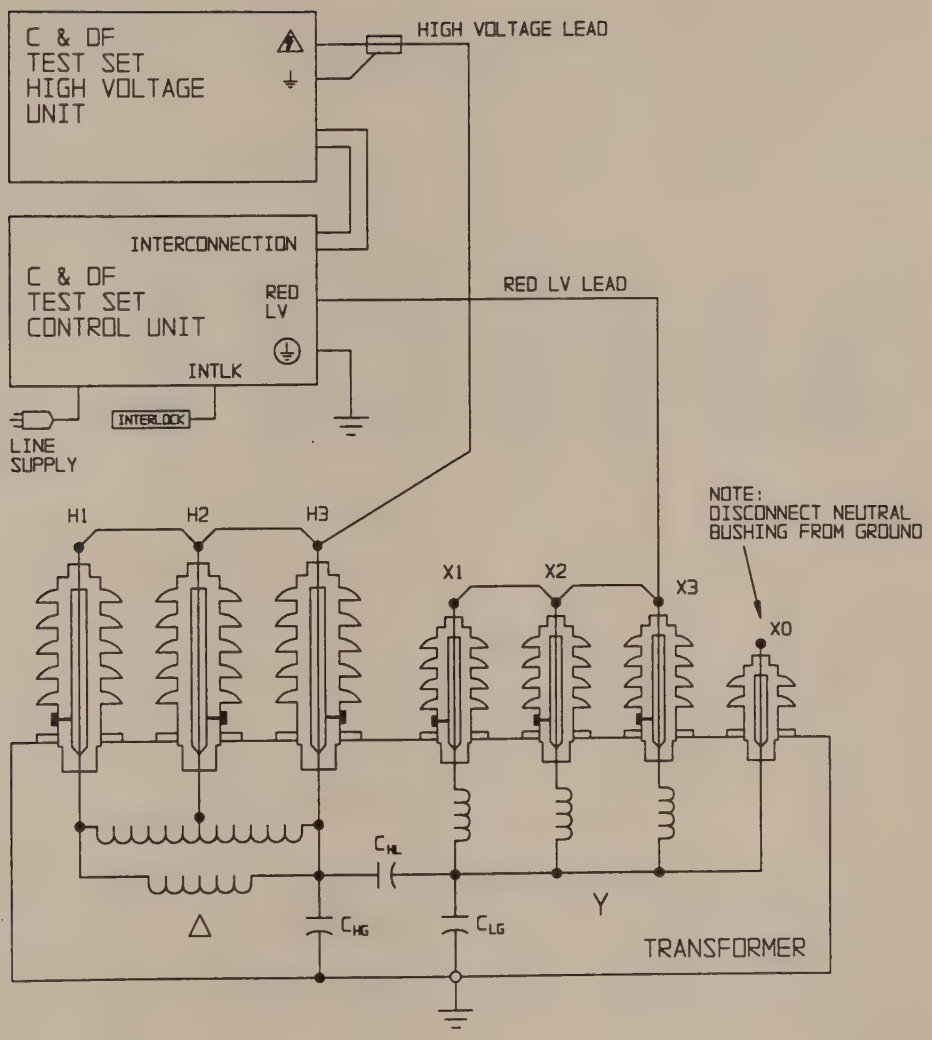


Figure 5: Typical Test Setup for Capacitance Measurements on a Three-Phase Power Transformer

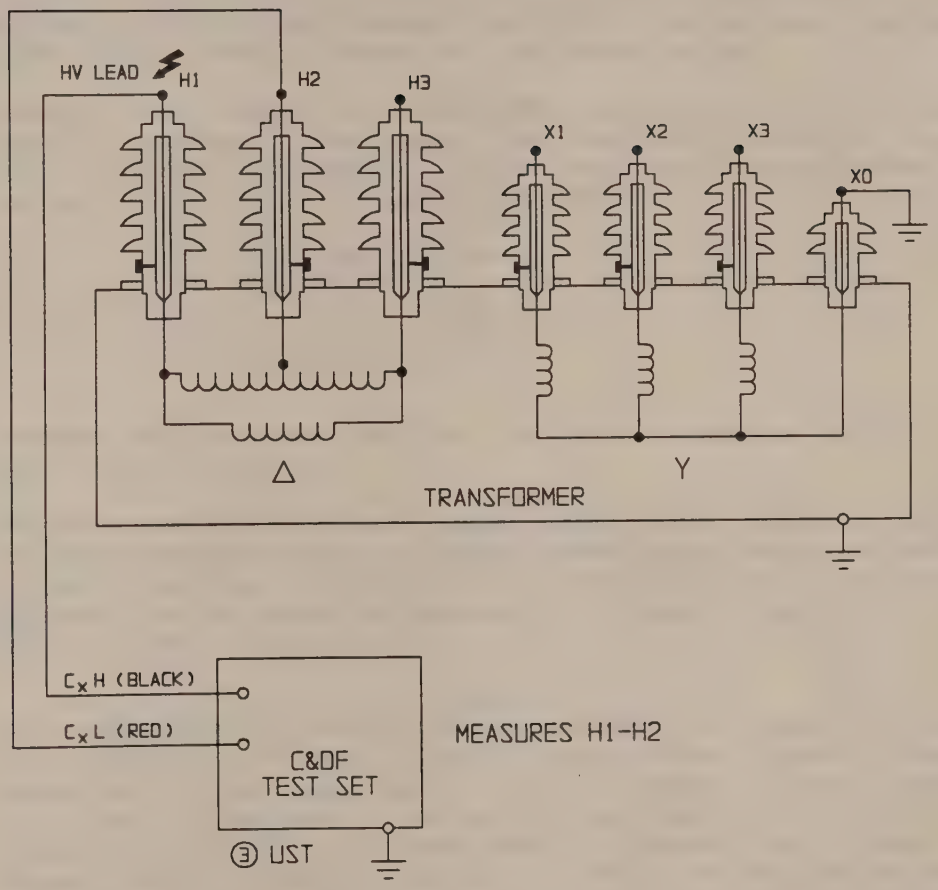
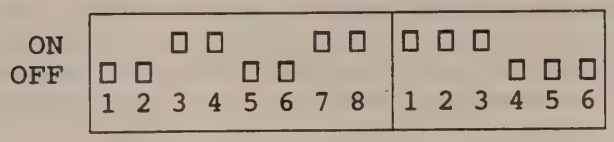


Figure 6: Typical Test Setup for Transformer Excitation Current Measurements

4. Connect the low-voltage cable with red colored boot to the RED LV receptacle (24). Make sure the connector locks to the receptacle. If required, connect the low-voltage cable with blue colored boot to the BLUE LV receptacle (25).

5. Connect the external interlock cable or a test area interlock system to the INTLK receptacle (23). Make sure the bayonet type plug is fully locked on the receptacle.

6. Connect the printer to the PRINTER receptacle (22) of the test set if desired. Make sure the bayonet type plug is fully locked on the receptacle. Make sure the dip switches on the bottom of the printer are set as shown:



7. Connect the bar code wand to the ID No. receptacle (10) of the test set if desired.

8. Connect the high-voltage cable with black boot to the high-voltage terminal (28) of the high-voltage unit. Connect the pigtail for the outer shield to the black binding post (29) (ground) on the high-voltage unit. Screw down the plug shell fully on the receptacle.

NOTE

The exposed metal shield ring nearest the hook on the outboard end of the high-voltage cable is at guard potential. The inner metal ring is ground. Both rings are undercut so that a battery or alligator clip may be attached to them for convenience in connection of short jumper leads to guard or ground. Keep the insulation at each end of this cable, as well as the high-voltage plug and receptacle, free from moisture and dirt during installation and operation. Clean as required with a clean, dry cloth or one moistened sparingly with alcohol.

9. With the main breaker OFF, plug the input power cord into the test set power receptacle (2) and into a three-wire grounded power receptacle having the appropriate voltage and current ratings.

10. Connect the crocodile clip of the low-voltage test cable to the desired terminal of the test specimen.

11. Connect the hook of the high-voltage test cable to the desired terminal of the test specimen.

When making capacitance measurements on transformer windings, always short each winding on itself with a jumper lead to eliminate winding inductance effect. When making transformer excitation current measurements, conduct all tests on high-voltage windings only. This reduces the required charging current. In load tap changers, set to fully raised or fully lowered position for routine tests.

DESCRIPTION OF MAIN MENU

The operation of the test set is controlled by using the LCD panel and the front panel controls and switches. On power up, the LCD displays the Biddle logo for 5 seconds. Before the display appears, the test set will have run a complete RAM check and will have initialized all the hardware and software variables. Then a beep sounds and the test set performs a diagnostic self-check of the electronics.

Test Screen

The main screen, the TEST screen (Fig. 7) then appears showing the test no., test mode, date, and time on the first line. Graphical headings for the tests to be performed are also shown. The last line, the sixteenth line, is the command line. The fourteenth and fifteenth lines are called the message and reply lines. The command line displays the function of the three buttons immediately below the display. For the initial screen with the PRINT/STORE option selected these are: MENU, ID NO., and HEADER.

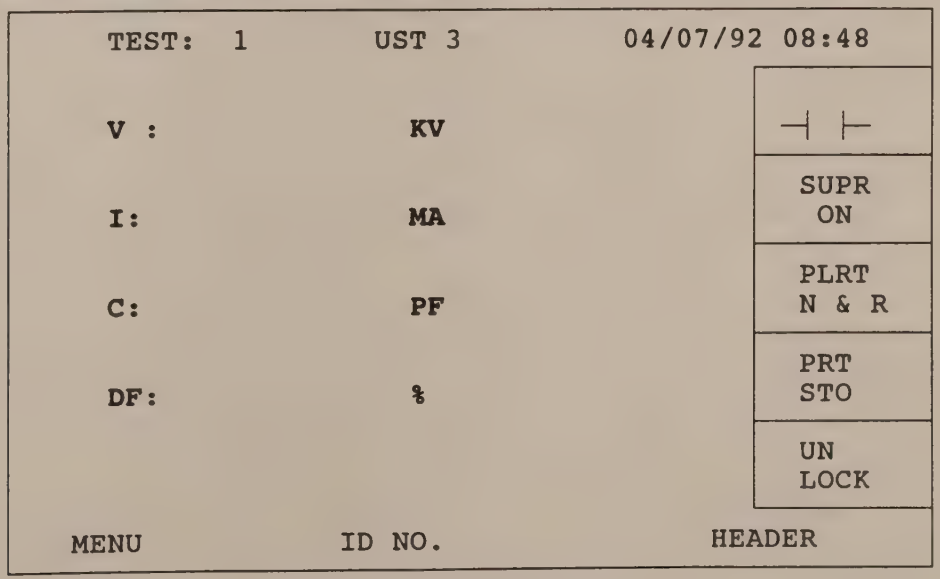


Figure 7: Test Screen

If STORE is selected, the HEADER message is not displayed. If NONE is selected, only the MENU message is displayed. The HEADER function sends a header record to the printer. The ID NO. function requests that the operator enter a test ID via the bar code wand. Data entered appears on the reply line. If PRINT/STORE or STORE is selected, the test set checks to see if a data key is present and, if not, asks the operator to PLEASE INSERT DATAKEY. To store data, the data key must be inserted. The MENU function displays the first of two menu screens. Menu operations allow the operator to change test parameters.

Operation Status Blocks

The operation status blocks shown on the right side of the TEST screen (Fig. 7) give continuous indication (status) of the activated operating functions. This feature allows the operator to make an initial setup and then make repetitive measurements without going back into the menu. The status blocks are further defined as follows:

⊣⊢	CAPACITANCE AND DF MEASUREMENT
⊣■⊢	TRANSFORMER EXCITING CURRENT MEASUREMENT
SUPR ON	INTERFERENCE SUPPRESSOR: TURNED ON
SUPR OFF	INTERFERENCE SUPPRESSOR: TURNED OFF
PLRT N&R	VOLTAGE POLARITY: NORMAL/REVERSE
PLRT NORM	VOLTAGE POLARITY: NORMAL ONLY
PRT STO	PRINT AND STORE READINGS: PRINT AND STORE
PRT	PRINT AND STORE READINGS: PRINT READINGS
STO	PRINT AND STORE READINGS: STORE READINGS
	PRINT AND STORE READINGS: NONE
UN LOCK	SET-UP LOCK: UNLOCKED
LOCK	SET-UP LOCK: LOCKED

First Menu Screen

The first menu screen is shown in Figure 8. The item selected is displayed in reverse video and the command line gives the options available. The center and right buttons display UP and DOWN on the screen, respectively. This permits the operator to move the cursor to the desired line. The selection sequence allows the display to wrap from the first line to the last line and vice versa. The display above the left button shows the function of this button and changes as different items are selected; either CHANGE or ENTER is displayed.

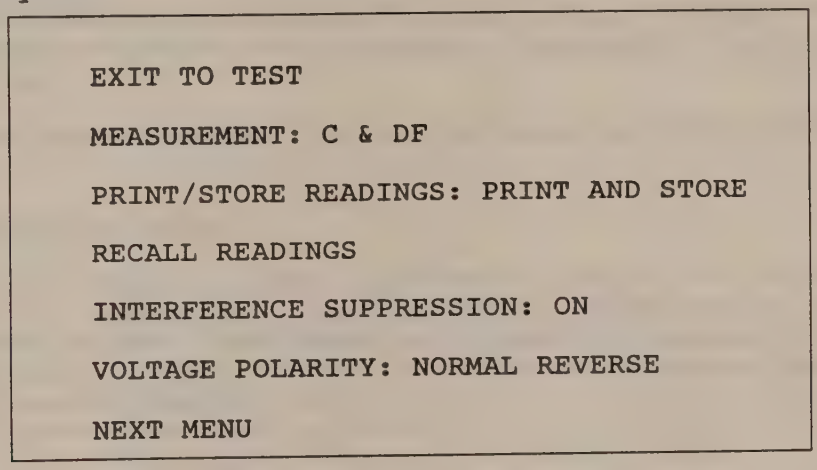


Figure 8: First Menu Screen

EXIT TO TEST returns the display to the TEST screen.

The MEASUREMENT line toggles between the C & DF test and the TRANS EXCITING CURRENT test.

The PRINT/STORE READINGS line toggles four ways: PRINT & STORE, PRINT, STORE, or NONE.

The RECALL READINGS selection displays a submenu, see Figure 9.

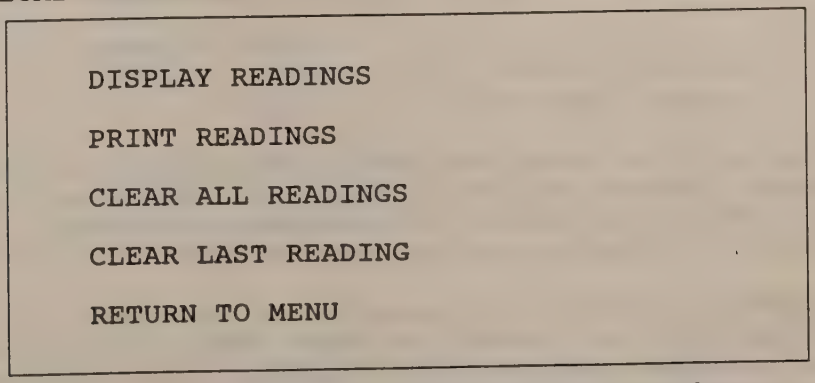


Figure 9: Recall Readings Submenu

A data key must be inserted in its receptacle for this option to be selected. For the DISPLAY READINGS and PRINT READINGS options, the operator is requested to enter the start test number and then the number of tests to be displayed or printed. The center (RAISE) and right (LOWER) buttons increase or decrease the value displayed. The left button (OK) selects the value. The CLEAR ALL READINGS and CLEAR LAST READING selections prompt with the message ARE YOU SURE. A YES response is entered by pressing both the center and right buttons simultaneously. A NO response is entered by pressing either the left button or only one of the other buttons.

The INTERFERENCE SUPPRESSION line toggles between ON and OFF and determines whether interference suppression is performed during testing.

The VOLTAGE POLARITY line toggles between NORMAL/REVERSE or NORMAL ONLY.

Second Menu Screen

The NEXT MENU line when selected displays the second menu screen shown in Figure 10. Another method of selecting this menu from anywhere on the first menu is to press the center and right (UP and DOWN) buttons simultaneously. This also returns the screen to the first menu from this menu.

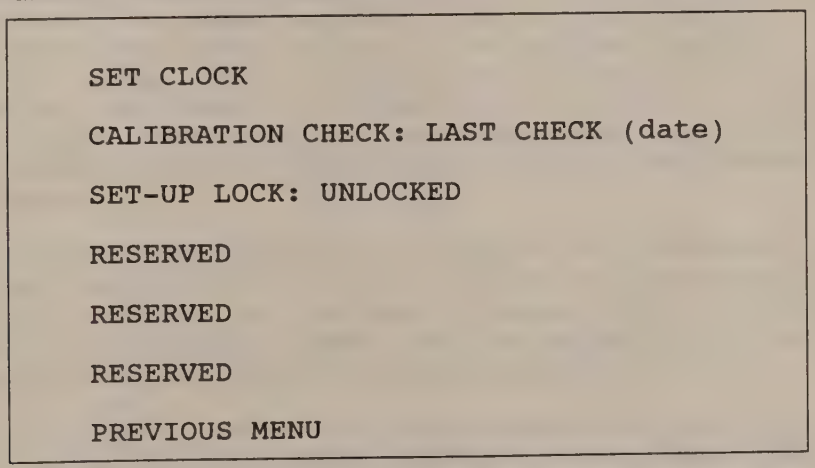


Figure 10: Second Menu Screen

The SET CLOCK function allows the operator to correct the date and time. The clock is deactivated at the factory to save the battery power. When the test set is turned on for the first time, the clock is activated and the time and date set to zeros.

When this function is selected, the operator is asked if he wants to use the bar code wand for input. A YES response allows the operator to enter the date and time one character at a time. All characters must be entered, including any zeros. The cursor blinks

under the character to be entered and moves as the characters are received. Only the numbers need to be entered as the cursor skips the /, space, and : characters. A NO response means that the date and time will be updated by the buttons below the LCD panel. The command line displays from left to right: OK, RAISE, and LOWER, corresponding to the buttons below the display. The two characters of the month are shown in reverse video. Use the RAISE and LOWER buttons to select the correct month. The numbers will wrap from 01 to 12 and vice versa. When the month is correct, press the OK button. The display will then show the day field in reverse video. perform the same functions for each field in the display. After entering OK after the minutes, the display returns to the menu screen. The date and time will automatically be updated by the system.

The CALIBRATION CHECK: LAST CHECK display line shows when the test set was last calibrated. It is also used to start a calibration test. This is the long calibration routine and requires the unit be removed from the case so that there is access to the calibration switch on the microprocessor board.

The SET-UP LOCK: function permits the menu system to be locked so that the operator cannot change any of the selected parameters. In the unlocked mode, the operator can enter the menu system from the TEST screen. In the locked mode, the menu button does not permit access to the menu system. The system should be set up in accordance with the method of doing the testing, selecting the default values for suppression, print/store, normal/reverse. Selecting this function locks the menu system and returns to the TEST screen. The operator can make measurements, change the test mode, print, and/or store the results, but cannot change test parameters.

This feature is included to prevent unauthorized personnel from changing the default settings. If deemed necessary by supervisory personnel, access to the menu system after the display has been placed in the locked mode can be gained by pressing all three buttons below the display simultaneously.

The next three line entries, RESERVED, are just that, reserved for future expansion for POWER FACTOR TIP-UP, DEVIATION READINGS, and PASS/FAIL LIMITS.

The last item, PREVIOUS MENU, returns the screen to the first line of the first menu screen. Pressing the center and right buttons simultaneously also returns the screen to the first menu screen from anywhere in this menu.

MEASUREMENT (CAPACITANCE AND DISSIPATION FACTOR)

Proceed only after fully understanding Section 2, Safety, and setting up the test set as described. An operator who is familiar with the contents of this manual, the test setup, and the operation of the test set may follow the condensed operating procedure in the lid of the test set. The LCD panel and the front panel controls and switches are the means that the operator has to control operation of the test set. Refer to Section 4, Controls, Indicators and Connectors; also Section 5 DESCRIPTION OF MAIN MENU. The following instructions are the normal procedures for conducting a test, with print and store functions enabled.

1. Remove all safety grounds from the specimen to be tested.

2. To store data, insert a data key into the receptacle on the front panel and turn it one quarter turn clockwise.

3. Close the main breaker. The white POWER lamp should light. The Biddle logo is displayed for 5 seconds, and then the test screen displayed.

4. Adjust CONTRAST control for desired viewing angle of screen.

5. Examine the operation status blocks on the TEST screen (Fig. 7) to see if test set is set up to make measurements in the desired manner. If necessary, press MENU switch and make required changes. Refer to MAIN MENU section.

6. At this time (preferred), the operator can print a header or enter the equipment ID NO. Entry can also be made after a test has been completed. Press the HEADER switch to send a header record to the printer. Press the ID NO. switch to enter a test ID NO. The operator will then be requested to enter a test ID NO. on the message line via the bar code wand.

7. Select desired measurement TEST MODE by pressing appropriate UST/GST switch button. The test mode number selected will appear on the top line of the TEST screen.

8. Close the external interlock switch.

9. Set the OUTPUT VOLTAGE CONTROL to ZERO START.

10. Press the white HV ON push-button switch when ready to energize the high-voltage circuit. The red HIGH VOLTAGE lamp should light, and two high-voltage flash symbols should appear on the screen.

11. Adjust the OUTPUT VOLTAGE CONTROL to obtain the desired test voltage. Test voltage and current values are shown on the screen.

12. Press the SINGLE MEAS OPERATION switch (normally) when ready to make a measurement. This will light the red TESTING lamp and initiate a single measurement test. The word SINGLE will appear at the bottom right corner of the display. When completed, test voltage is removed from the specimen and test results indicated in the display. A typical test result is shown in Figure 11. The red HIGH VOLTAGE lamp will remain lit, indicating that the HV circuit is still enabled. The red TESTING lamp will be extinguished.

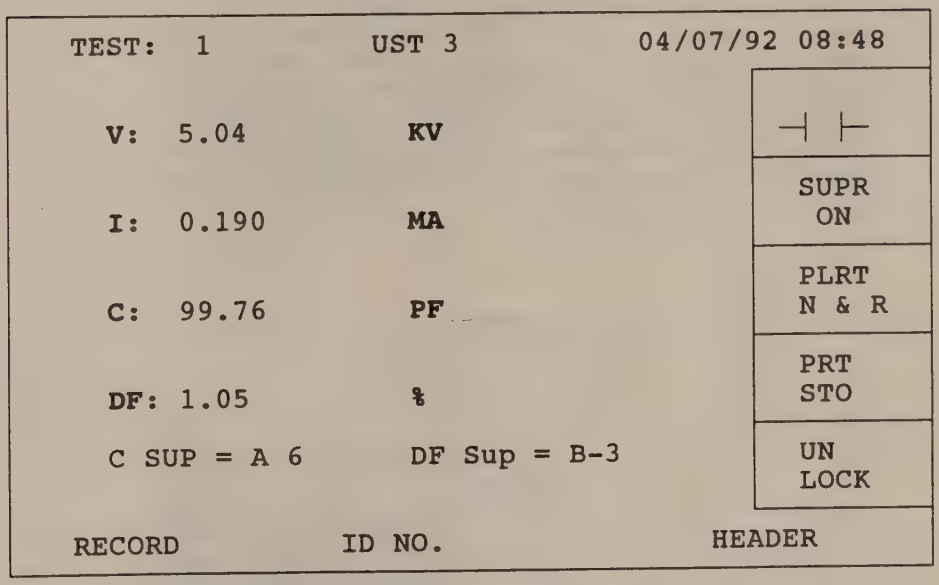


Figure 11: Typical Test Result Screen

When the interference suppressor is turned ON, the relative level of interference is measured and then displayed on the screen message line. The relative level range is A±0 through A±9, B±0 through B±9, C±0 through C±9 with A0 indicating minimum interference level and C9 indicating maximum interference level. Knowing the relative level of interference serves as an aid to test personnel in judging the accuracy of a measurement. The higher the interference level, the higher the probability of reduced accuracy.

13. Press the HEADER switch to send a header record to the printer or ID NO. switch to send an ID NO. to storage or to the printer if it was not previously entered in step 6. Press the RECORD switch to store test results and send test results to the printer. The test number appears on the top line of the test screen. See Figure 12 for a sample printout of header and test results.

14. The operator may now select another UST/GST test mode by pressing the appropriate UST/GST switch button. The new test mode number will appear on the top line of the test screen.

AVO BIDDLE INSTRUMENTS
CAPACITANCE & DF TEST SET
CAT. NO. 672000

C & DF INSTRUMENT SER. NO.: _____
OPERATORS NAME: _____
EQUIPMENT IDENTIFCATION: _____
EQUIPMENT SER. NO.: _____
AMBIENT TEMPERATURE: _____
RELATIVE HUMIDITY: _____
COMMENTS/NOTE:

DATE: 4/10/92 08:03
TEST ID NO.: 23 SPC CAP
TEST MODE: UST 3
MEASUREMENT: C & DF
VOLTAGE: 12.03 KV
CURRENT: 9.04 MA
7.51 MA @ 10KV
CAPACITANCE: 1993.3 PF
DISSIPATION FACTOR: 0.00 %
POWER FACTOR: 0.00 %
WATTS: .0000 W @ 10KV
CSUP = A-0 DFSUP = A-0

Figure 12: Sample Printout C and DF Measurement

15. Press the RESTART HV OPERATION switch to reapply high voltage to the test specimen without a zero restart of the high-voltage circuit. If necessary, readjust the OUTPUT VOLTAGE CONTROL to obtain the desired test voltage.

16. Press SINGLE MEAS OPERATION switch when ready to make a measurement. When completed the new test results will be indicated on the display. It should be noted that the test number will increment for each test performed.

17. Press the RECORD switch to both store and print out the new test results.

18. Steps 14 through 17 may be repeated as many times as desired to repeat tests or select different UST/GST test modes.

19. When the tests have been completed, return the OUTPUT VOLTAGE CONTROL to the ZERO START position, press the red HV OFF push-button switch or open the external interlock switch, then switch the main breaker to OFF.

IN CASE OF EMERGENCY

High-voltage power can be interrupted immediately by pressing the red HV OFF push-button switch, opening the external interlock, or switching the main breaker OFF.

WARNING

Discharge specimen terminals with a safety ground stick to ground all live parts, then solidly ground these parts with safety ground jumpers before disconnecting the instrument leads. Always disconnect test cables from the specimen under test before attempting to disconnect them at the test set.

MEASUREMENT (TRANSFORMER EXCITATION CURRENT)

Proceed only after fully understanding Section, 2, Safety, and setting up the test set as described. See Figure 6. An operator who is familiar with the contents of this manual, the test setup, and the operation of the test set may follow the condensed operating procedure in the lid of the test set. The LCD panel and the front panel controls and switches are the means that the operator has to control operation of the test set. Refer to Section 4, Controls, Indicators and Connectors; also Section 5 MAIN MENU.

To reduce the required charging current, conduct all tests on high-voltage windings only. Shorted turns will still be detected in the low-voltage windings. Low-voltage windings which are grounded in service (such as X_o) should be grounded for this test.

Always apply the exact same test voltage to each phase of a three-phase transformer winding. This will minimize errors due to any nonlinearity between voltage and current. For this same reason subsequent tests on transformer windings, whether single or three-phase, should always be repeated at the exact same test voltage. On three-phase transformers, the excitation current is generally similar for two phases and noticeably lower for the third phase which is wound on the center leg of the core.

On single-phase transformers, the winding is normally energized alternately from opposite ends. This should also be done on delta windings of three-phase transformers if the excitation current is abnormal. The residual magnetism in the magnetic core will seldom affect routine tests; however, the probability should be considered if the excitation currents are abnormally high. Care should be exercised when energizing transformer windings so as not to exceed the voltage rating of the winding.

Load tap changers should be set to fully raised or fully lowered position for routine tests.

The following instructions are the normal procedures for conducting a transformer excitation current test, with print and store functions enabled.

1. Remove all safety grounds from the specimen to be tested.

2. To store data, insert data key in the key receptacle and turn one-quarter turn clockwise.

3. Close the main breaker. The white POWER lamp should light. The Biddle logo is displayed for 5 seconds and then the test screen displayed.

4. Adjust CONTRAST control for desired viewing angle of screen.

5. Examine the operator status blocks on the test set screen to see if test set is setup to make transformer excitation current measurements, and in the desired manner. For example, do you want to make measurements with NORMAL/REVERSE or NORMAL ONLY voltage polarity. If necessary, press MENU switch and make required changes. Refer to MAIN MENU section of manual.

6. At this time (preferred), the operator can print a header or enter the equipment ID NO. Entry can also be made after a test has been completed. Press the HEADER switch to send a header record to the printer. Press the ID NO. switch to enter a test ID NO. The operator will then be requested to enter a test ID NO. on the message line via the bar code wand.

7. Select desired measurement TEST MODE by pressing appropriate UST/GST switch button (UST 3 when making initial test per

Figure 6). The test mode number will appear on the top line of the TEST screen.

8. Close the external interlock switch.

9. Set the OUTPUT VOLTAGE CONTROL to the ZERO START position.

10. Press the white HV ON push-button switch when ready to energize the high-voltage circuit. The red HIGH VOLTAGE lamp should light, and two high-voltage flash symbols should appear on the screen.

11. Adjust the OUTPUT VOLTAGE CONTROL to obtain the desired test voltage. The test voltage and current values are shown on the test screen. The C: and DF: entries will be deleted.

12. Press the SINGLE MEAS OPERATION switch (normally) when ready to make a measurement. This will light the red TESTING lamp and initiate a single measurement test. The word SINGLE will appear at the bottom right corner of the display. When completed, test voltage is removed from the specimen and test results indicated in the display. A typical test result is shown in Figure 13. The red HIGH VOLTAGE lamp will remain lit, indicating that the HV circuit is still enabled. The red TESTING lamp will be extinguished.

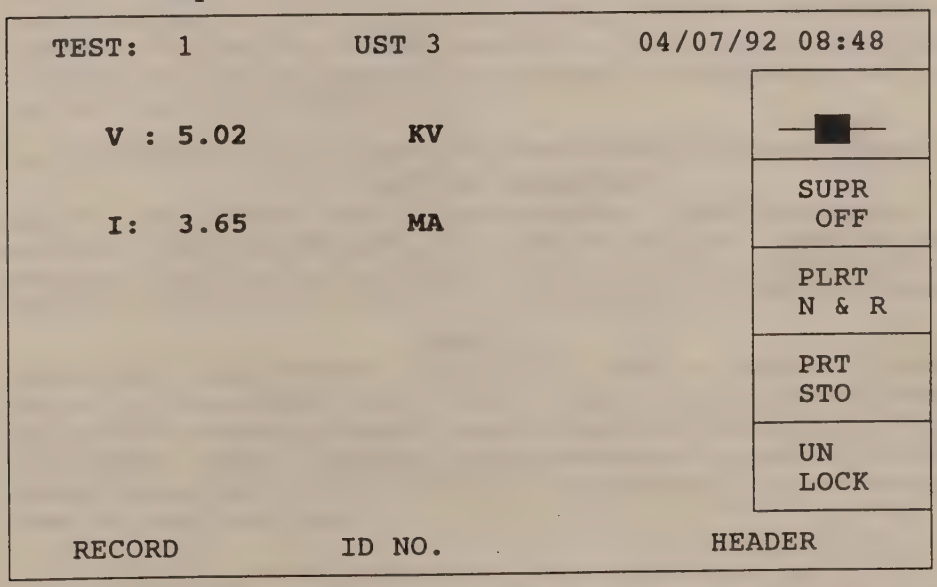


Figure 13: Test Results, Transformer Excitation Current

It should be noted that the interference suppressor is **always** turned OFF when making transformer excitation current measurements. The operation status block however may display either SUPR ON or SUPR OFF.

13. Press the HEADER switch to send a header record to the printer or ID NO. switch to send an ID NO. to storage or to the printer if it was not previously entered in step 6. Press the RECORD switch to store test results and send test results to the printer. The test number appears on the top line of the test screen. See Figure 14 for a sample printout of header and test results.

14. To repeat a measurement press the RESTART HV OPERATION switch which will reapply high-voltage to the transformer winding without a zero restart of the high-voltage circuit. If necessary readjust the OUTPUT VOLTAGE CONTROL to obtain the desired test voltage.

15. Press SINGLE MEAS OPERATION switch when ready to repeat the measurement. When completed the new test results will be indicated in the display. It should be noted that the test number will increment for each test performed.

16. Press the RECORD switch to both store and print out the new test results.

17. Steps 14 through 16 may be repeated as many times as desired to repeat a measurement.

18. When the tests have been completed, return the OUTPUT VOLTAGE CONTROL to the ZERO START position, press the red HV OFF push-button switch or open the external interlock switch, then switch the main breaker OFF.

IN CASE OF EMERGENCY

High-voltage power can be interrupted immediately by pressing the red HV OFF push-button switch, opening the external interlock, or switching the main breaker OFF.

WARNING

Discharge transformer terminals with a safety ground stick to ground all live parts, then solidly ground these parts with safety ground jumpers before disconnecting the instrument leads. Always disconnect test cables from the transformer under test before attempting to disconnect them at the test set.

AVO BIDDLE INSTRUMENTS
CAPACITANCE & DF TEST SET
CAT. NO. 672000
C & DF INSTRUMENT SER. NO.: _____
OPERATORS NAME: _____
EQUIPMENT IDENTIFCATION: _____
EQUIPMENT SER. NO.: _____
AMBIENT TEMPERATURE: _____
RELATIVE HUMIDITY: _____
COMMENTS/NOTE:

DATE: 4/10/92 07:24
TEST ID NO.: 18 UST 65-3
TEST MODE: UST 3
MEASUREMENT: TRANS EXCITING CURRENT
VOLTAGE: 5.02 KV
CURRENT: 3.65 MA
7.27 MA @ 10KV

Figure 14: Sample Printout of Excitation Current Measurement

Section 6

Application Notes

PRINCIPLE OF OPERATION

Most physical capacitors can be accurately represented as a two or three-terminal network as shown in Figure 15. The direct capacitance between the terminals H and L is represented by C_{HL} while the capacitances between each respective terminal and ground are represented by C_{HG} and C_{LG}. In the two-terminal capacitor the L terminal is connected to ground.

An example of a two-terminal capacitor is an apparatus bushing. The center conductor is one terminal and the mounting flange (ground) the second terminal. An example of a three-terminal capacitor is an apparatus bushing which has a power factor or capacitance tap. The center conductor is one terminal, the tap is the second terminal, and the mounting flange (ground) the third terminal.

It is possible to have a complex insulation system which has four or more terminals. A direct measurement of any capacitance component in a complex system can be made with this test set since it has the capability for measuring both ungrounded and grounded specimens.

Figure 16 shows a simplified measuring circuit diagram of the test set when operating in the UST 3 test mode. The basic bridge circuit uses a three-winding differential current transformer. The ampere-turns due to the current i_x through the test specimen (C_{HL}) are balanced by the ampere-turns due to the current i_s passing through the reference capacitor (C_s). The same voltage is applied to the two capacitors by the power supply. An ampere-turn balance is obtained for the quadrature (capacitance) component of current by automatic adjustment of the N_x and N_s turns. The value of the capacitance is then displayed on the LCD.

Since the specimen current includes both an in-phase component (leakage) and a quadrature component (capacitive) of current, a residual difference current will appear in the third winding after the capacitance has been balanced. This represents the leakage (loss) component of current. This current component is also automatically balanced to produce a dissipation factor (watts/milliwatts) balance. The % dissipation factor/watts/milliwatts is displayed on the LCD.

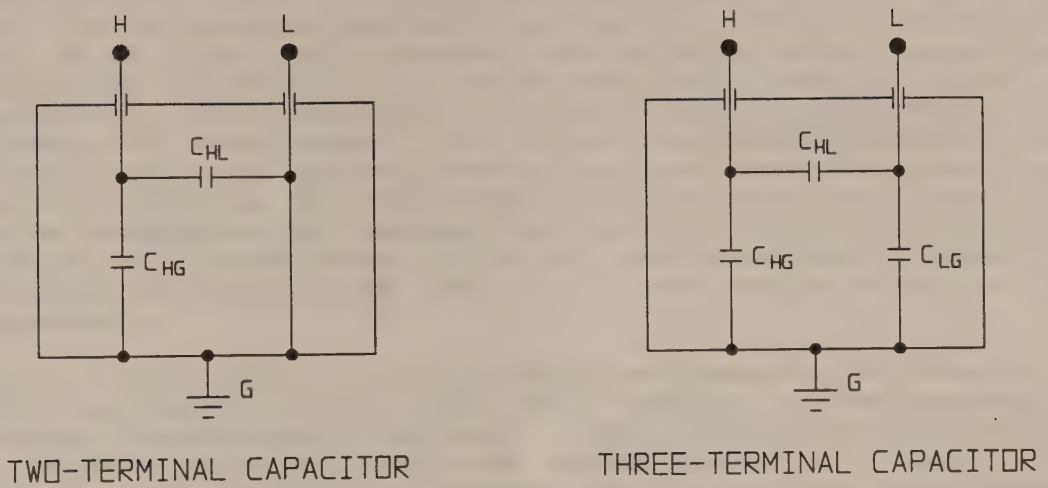


Figure 15: Two and Three Terminal Capacitors

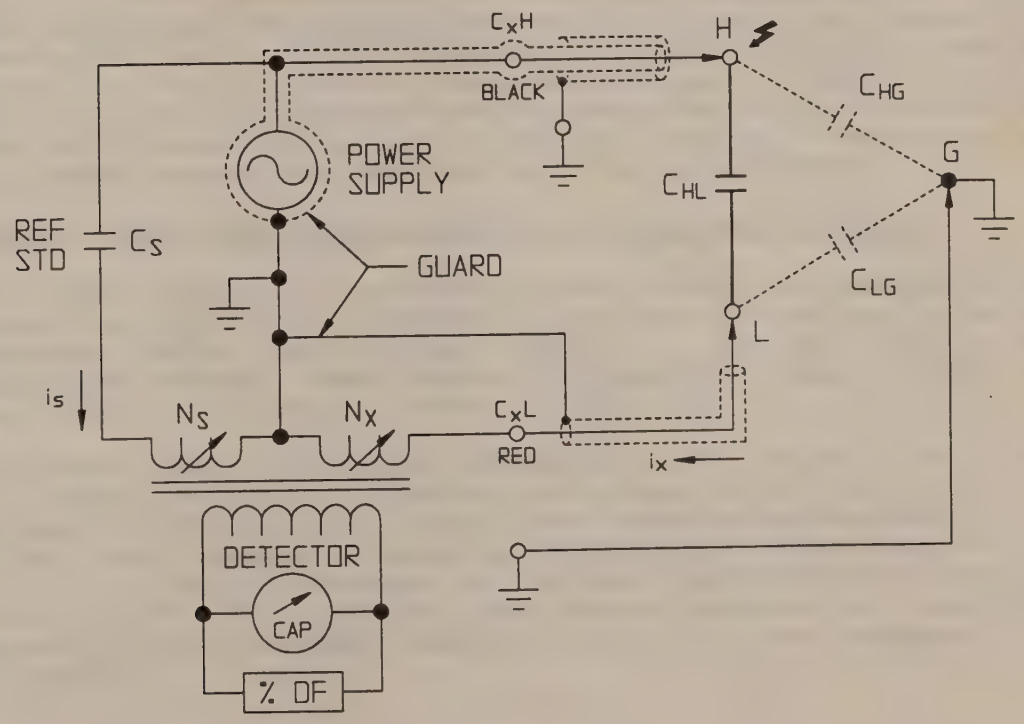


Figure 16: Simplified Measuring Circuit Diagram, UST 3 Test Mode

Figure 16 also shows how guarding is accomplished in the UST test mode. The bridge measures the capacitance C_{HL} which is shown by the heavy solid line. All internal and external stray capacitance between the high-voltage H terminal and guard (ground) shunts the power supply, where it affects only the supply loading and does not influence the measurement. All stray capacitance between the L terminal and guard (ground) shunts the N_x bridge winding and also does not influence the measurement. In practice the transformer winding resistance and leakage inductance is very small so that a large value of capacitance (>2000 pF) can be allowed to shunt the N_x bridge winding before there is a noticeable error in the measurement.

Figure 17 shows the measuring circuit and guarding for the GST L-GROUND test mode. In this test the L terminal of the specimen is grounded (two-terminal specimen). The bridge measures the two capacitances shown by the heavy solid lines (C_{HL} + C_{HG}). All internal stray capacitance between the C_xH lead and guard shunts the power supply, whereas the stray capacitance between guard and ground shunts the N_x bridge winding, therefore, both internal stray capacitances are excluded from the measurement for the same reasons as for the UST test method.

Figure 18 shows the measuring circuit and guarding for the GST L-GUARD test mode. The bridge measures the capacitance shown by the heavy solid line (C_{HG}). All internal and external stray capacitance between the high-voltage H terminal and guard shunts the power supply, whereas all internal and external stray capacitance between guard and ground shunts the N_x bridge winding; therefore, both stray capacitances are excluded from the measurement.

CURRENT, CAPACITANCE AND DISSIPATION FACTOR RELATIONSHIP

In an ideal insulation system connected to an alternating voltage source, the capacitance current I_c and the voltage are in perfect quadrature with the current leading. In addition to the capacitance current, there appears in practice a loss current I_r in phase with the voltage as shown in Figure 19.

The current taken by an ideal insulation (no losses, $I_r = 0$) is a pure capacitive current leading the voltage by 90° ($\theta = 90°$). In practice, no insulation is perfect but has a certain amount of loss and the total current I leads the voltage by a phase angle θ ($\theta < 90°$). It is more convenient to use the dielectric-loss angle δ, where $\delta = (90° - \theta)$. For low power factor insulation I_c and I are substantially of the same magnitude since the loss component I_r is very small.

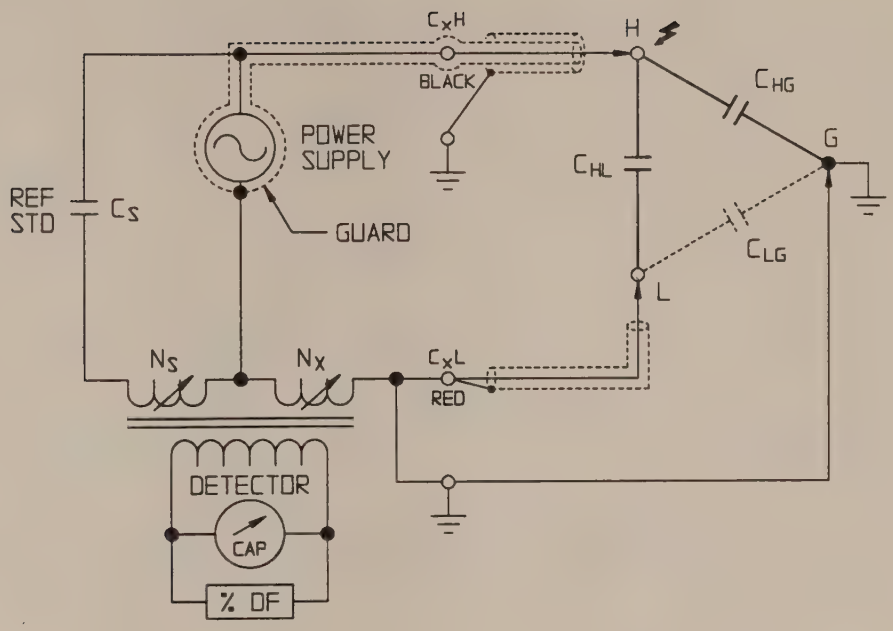


Figure 17: Simplified Measuring Circuit Diagram, GST L-GROUND 4 Test Mode

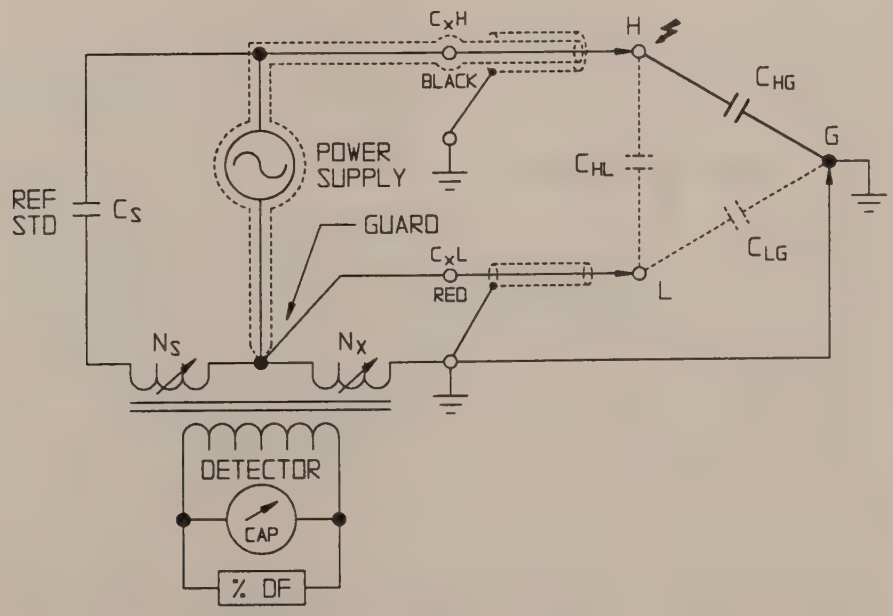


Figure 18: Simplified Measuring Circuit Diagram, GST L-GUARD 5 Test Mode

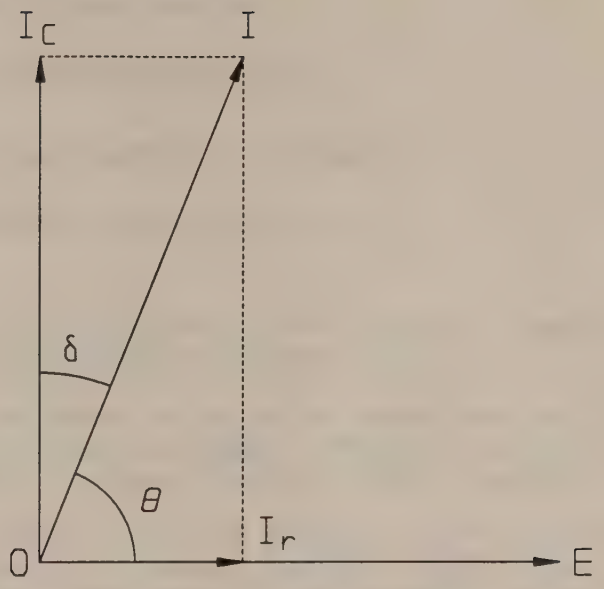
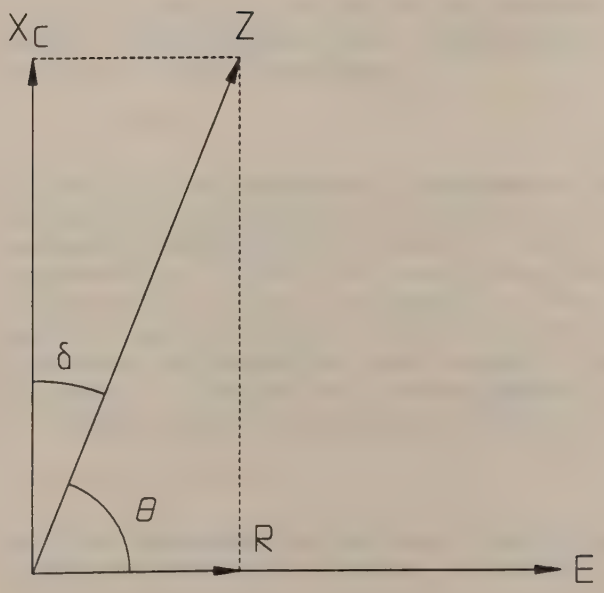


Figure 19: Vector Diagram Insulation System



$$\tan \delta = \frac{R}{X_c} = R\omega C$$

$$X_c = \frac{1}{\omega C}$$

Figure 20: Vector Diagram Showing Resistance and Reactance

The power factor is defined as:

$$\textit{Power factor} = \cos \Theta = \sin \delta = \frac{I_r}{I}$$

and the dissipation factor is defined as:

$$\textit{Dissipation factor} = \cos \Theta = \tan \delta = \frac{I_r}{I_c}$$

This test set is calibrated for direct reading in terms of capacitance and dissipation factor (tan δ).

The important characteristic of a capacitor is the ratio of its loss resistance to its reactance, which is the dissipation factor. This relationship is shown in the vector diagram of Figure 20.

In cases where angle δ is very small, sin δ practically equals tan δ. For example, at power factor values less than 10% the difference will be less than 0.5% of reading while for power factor values less than 20% the difference will be less than 2% of reading.

The value of I_c will be within 99.5% of the value I for power factor (sin δ) values up to 10% and within 98% for power factor values up to 20%.

If it is desired to find the value of the charging current I_c at a given test voltage and frequency, it may be determined from the following relationship:

$$I_c = V\omega C$$

In reality a capacitor possesses both a series and parallel loss resistance as shown in Figure 21. The frequency of the applied voltage determines which loss dominates, however, at low frequencies (50/60 Hz) only the parallel losses R_p, predominately generated in the dielectric, are generally measured. For a particular frequency, any loss can be expressed in terms of either a series or parallel equivalent circuit with equal accuracy. The choice is a matter of convenience. The dissipation factor (tan δ) for the series equivalent circuit is defined as:

$$\tan \delta = R_s \omega C_s$$

To find the equivalent parallel impedance C_p and R_p, the conversion formulas shown in Figure 22 must be used.

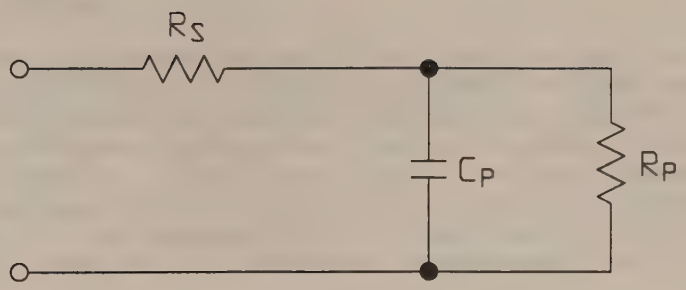
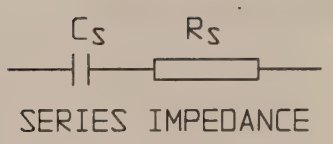


Figure 21: Equivalent Circuit for Capacitor Losses

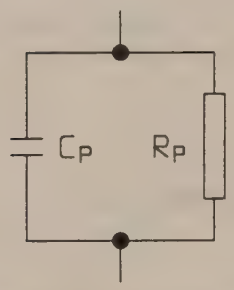
$$\tan \delta = \frac{1}{R_p \omega C_p}$$

$$C_p = \frac{C_s}{1 + \tan^2 \delta_s} = \frac{C_s}{1 + (R_s \omega C_s)^2}$$

$$R_p = R_s \left(1 + \frac{1}{\tan^2 \delta_s}\right) = R_s \left(1 + \frac{1}{(R_s \omega C_s)^2}\right)$$



SERIES IMPEDANCE



PARALLEL IMPEDANCE

Figure 22: Series - Parallel Equivalent Circuit

CONVERSION FORMULAS

Use the following formulas and the chart shown in Figure 23 to compare the capacitance reading obtained on the Biddle test set against the milliampere reading obtained on the Doble test set as well as the Biddle dissipation factor reading versus the Doble watts loss reading. The Doble mVA and mW readings, even if obtained at reduced test voltages, are generally recorded in terms of equivalent 2.5 kV values (2.5 kV test set) or equivalent 10 kV values (10 kV test set). Relevant nomographs are in Appendix C.

NOTE

Capacitance, dissipation factor, power factor, watts at 10 kV, current, and current at 10 kV can all be read directly from the test set. These formulas are provided for informational purposes only.

Conversion Formulas for test at 2.5 kV, 60 Hz
(based on Doble equivalent 2.5 kV values)

$C_{pF} = mA \times 1061$

$mA = C_{pF} \times 94.3 \times 10^{-5}$

Applicable when DF (PF) is less than 20%

$$\%DF = \frac{W_{loss} \times 40}{mA}$$

$W_{loss} = C_{pF} \times \%DF \times 23.6 \times 10^{-6}$

No limitation

Conversion Formulas for test at 10 kV, 60 Hz
(based on Doble equivalent 10 kV values)

$C_{pF} = mA \times 265$

$mA = C_{pF} \times 377 \times 10^{-5}$

Applicable when DF (PF) is less than 20%

$$\%DF = \frac{W_{loss} \times 10}{mA}$$

$W_{loss} = C_{pF} \times \%DF \times 377 \times 10^{-6}$

No limitation

Conversion Formulas for test at 2.5 kV, 50 Hz
(based on Doble equivalent 2.5 kV values)

$C_{pF} = mA \times 1273$

$mA = C_{pF} \times 78.6 \times 10^{-5}$

Applicable when DF (PF) is less than 20%

$$\%DF = \frac{W_{loss} \times 40}{mA}$$

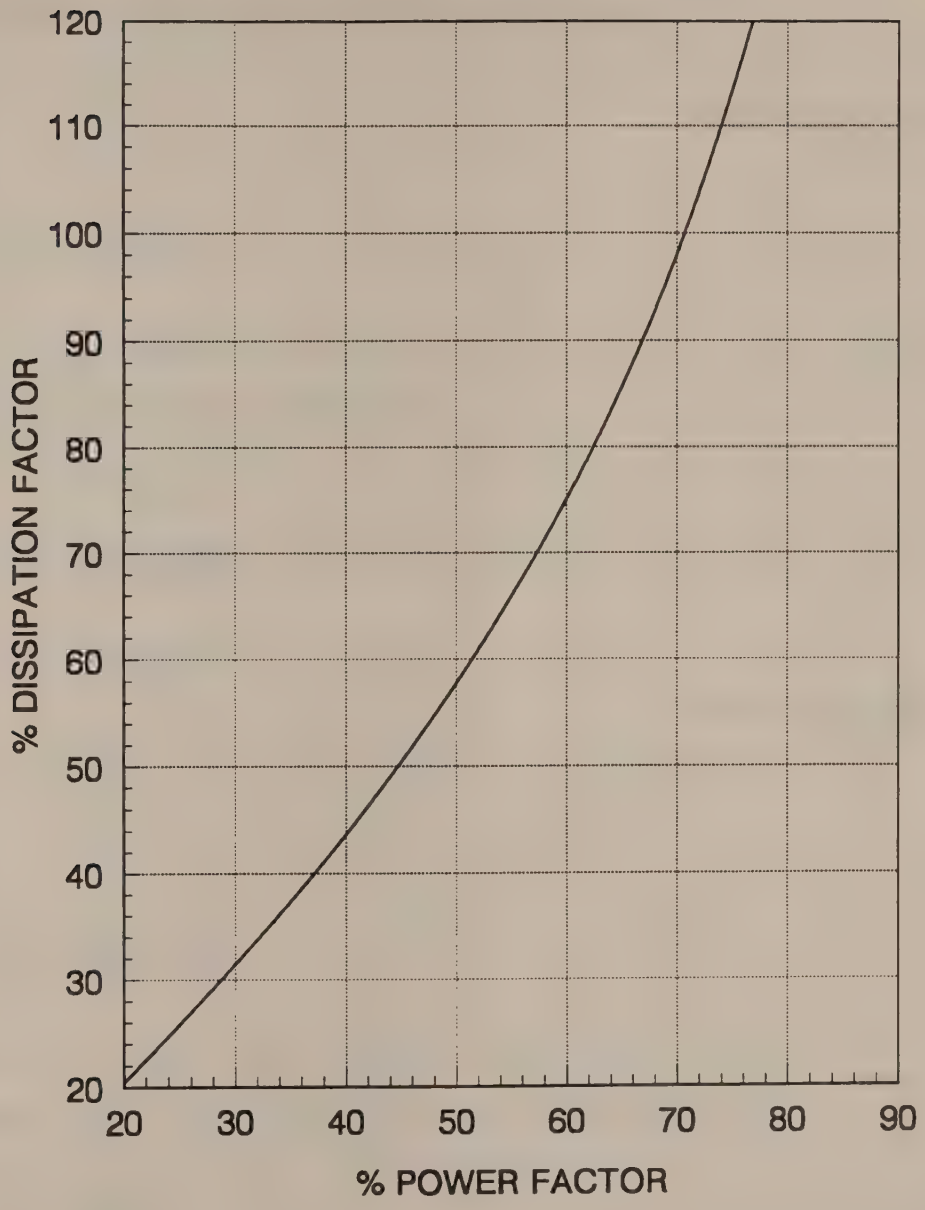


Figure 23: Graph for Converting Power Factor vs. Dissipation Factor

$W_{loss} = C_{pF} \times \%DF \times 19.6 \times 10^{-6}$ No limitation

Conversion Formulas for test at 10 kV, 50 Hz
(based on Doble equivalent 10 kV values)

$C_{pF} = mA \times 318$

$mA = C_{pF} \times 314 \times 10^{-5}$ Applicable when DF (PF) is less than 20%

$$\%DF = \frac{W_{loss} \times 10}{mA}$$

$W_{loss} = C_{pF} \times \%DF \times 314 \times 10^{-6}$ No limitation

General Conversion Formulas

$C_{pF} = \frac{mA \times 10^{6}}{\varpi \ kV}$

$C_{pF} = \frac{mA \times 2650}{kV}$ @ 60 Hz

$C_{pF} = \frac{mA \times 3180}{kV}$ @ 50 Hz

$mA = kV \ \varpi \ C_{pF} \times 10^{-6}$ Applicable when DF (PF) is less than 20%

$mA = kV \times C_{pF} \times 377 \times 10^{-6}$ @ 60 Hz

$mA = kV \times C_{pF} \times 314 \times 10^{-6}$ @ 50 Hz

$$\%DF = \frac{W_{loss} \times 100}{kV \times mA}$$

$W_{loss} = kV^2 \times C_{pF} \times \%DF \times 3.77 \times 10^{-6}$ @ 60 Hz

$Wloss = kV^2 \times C_{pF} \times \%DF \times 3.14 \times 10^{-6}$ @ 50 Hz No limitation

$$PF = \frac{DF}{\sqrt{1 + DF^2}}$$

No limitation

$$DF = \frac{PF}{\sqrt{1 - PF^2}}$$

where:

C_{pF} = capacitance, picofarads
DF = dissipation factor
mA = milliamperes
PF = power factor
kV = kilovolts
ϖ = $2\pi f$
W_{loss} = watts loss
f = frequency

CONNECTIONS FOR UST/GST TEST MODES

Figures 24 through 27 show the specific connections between the test set and specimen for each setting of the UST/GST test mode selector switch. The following chart shows the specific component of capacitance and dissipation factor which is measured for each setting of the UST/GST test mode selector switch, as well as how the test set automatically connects the low-voltage red and blue CxL test leads to either guard or ground in the bridge circuit. The component measured is shown by the heavy solid line in Figures 24 through 27. Measurements are always made between the CxH (black boot) high-voltage lead and the lead referenced in the MEASURES column.

UST/GST TEST MODE SELECTOR SWITCH SETTINGS

UST

TEST MODE	MEASURES	GROUNDS
1	R + B	-
2	B	R
3	R	B

GST L-GROUND

TEST MODE	MEASURES	GROUNDS
4	R + B + G	R + B

GST L-GUARD

TEST MODE	MEASURES	GUARDS	GROUNDS
5	G	R + B	-
6	R + G	B	R
7	B + G	R	B

R = Red
B = Blue
G = Green

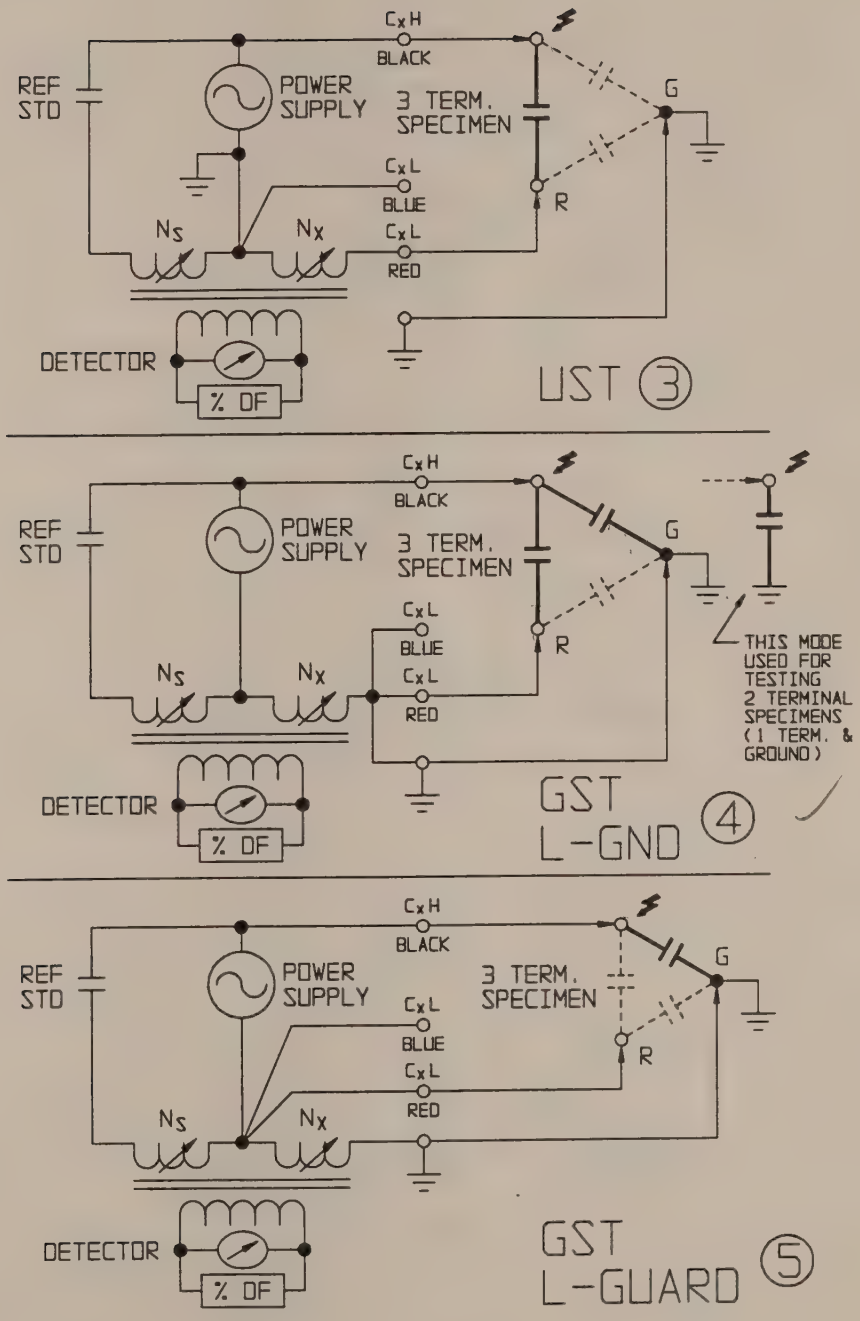


Figure 24: Connection for Three-Terminal Specimen, Test Modes 3, 4, and 5

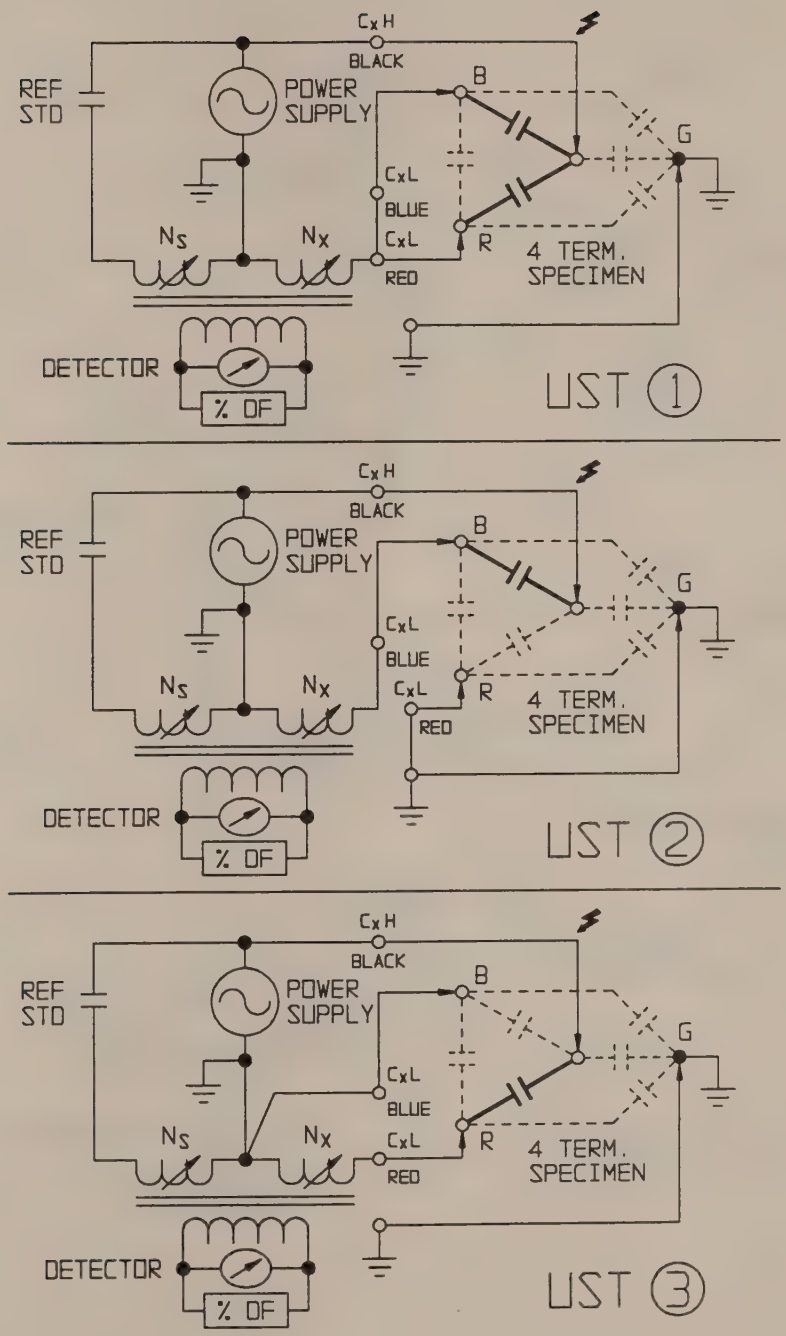


Figure 25: Connection for Four-Terminal Specimen, Test Modes 1, 2, and 3

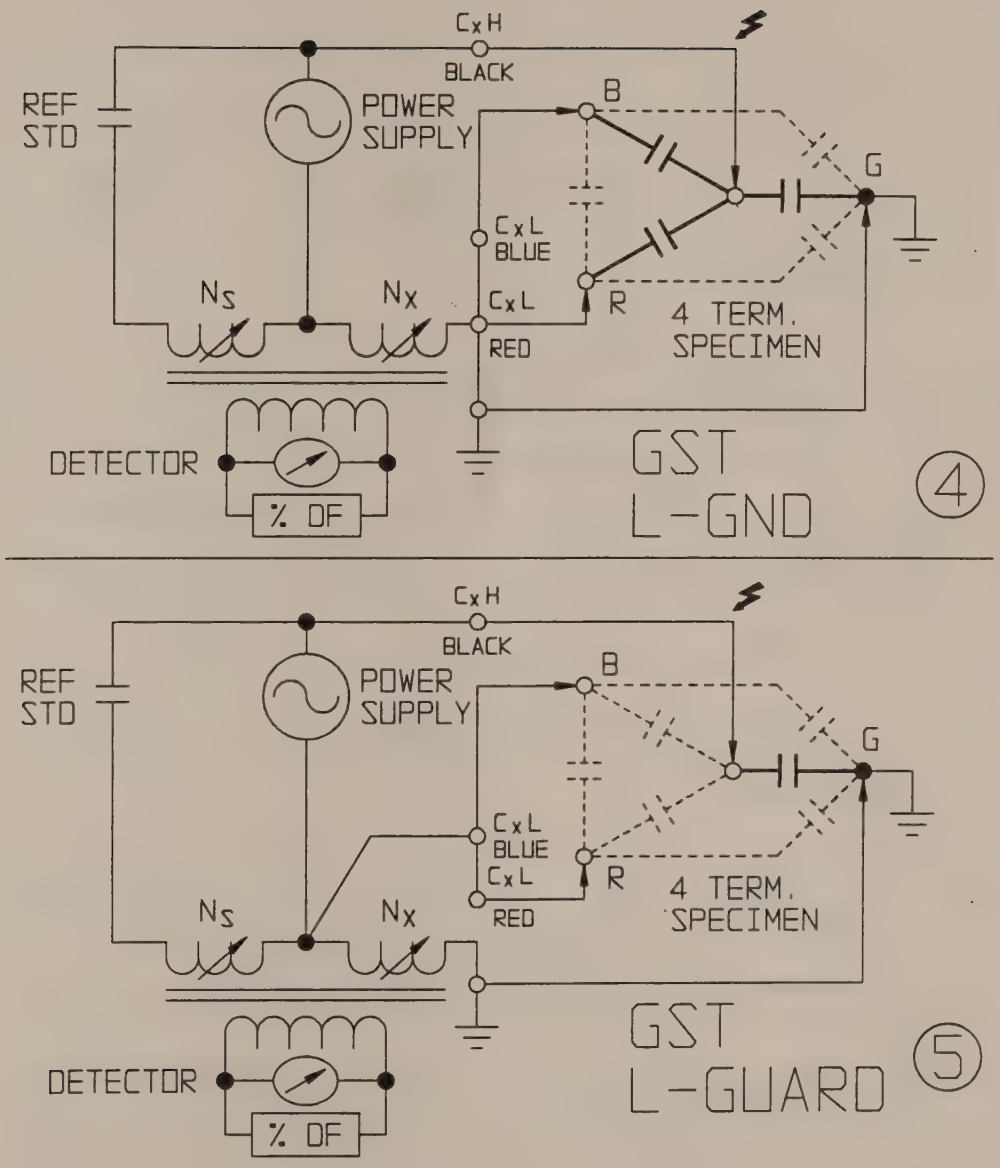


Figure 26: Connection for Four-Terminal Specimen, Test Modes 4 and 5

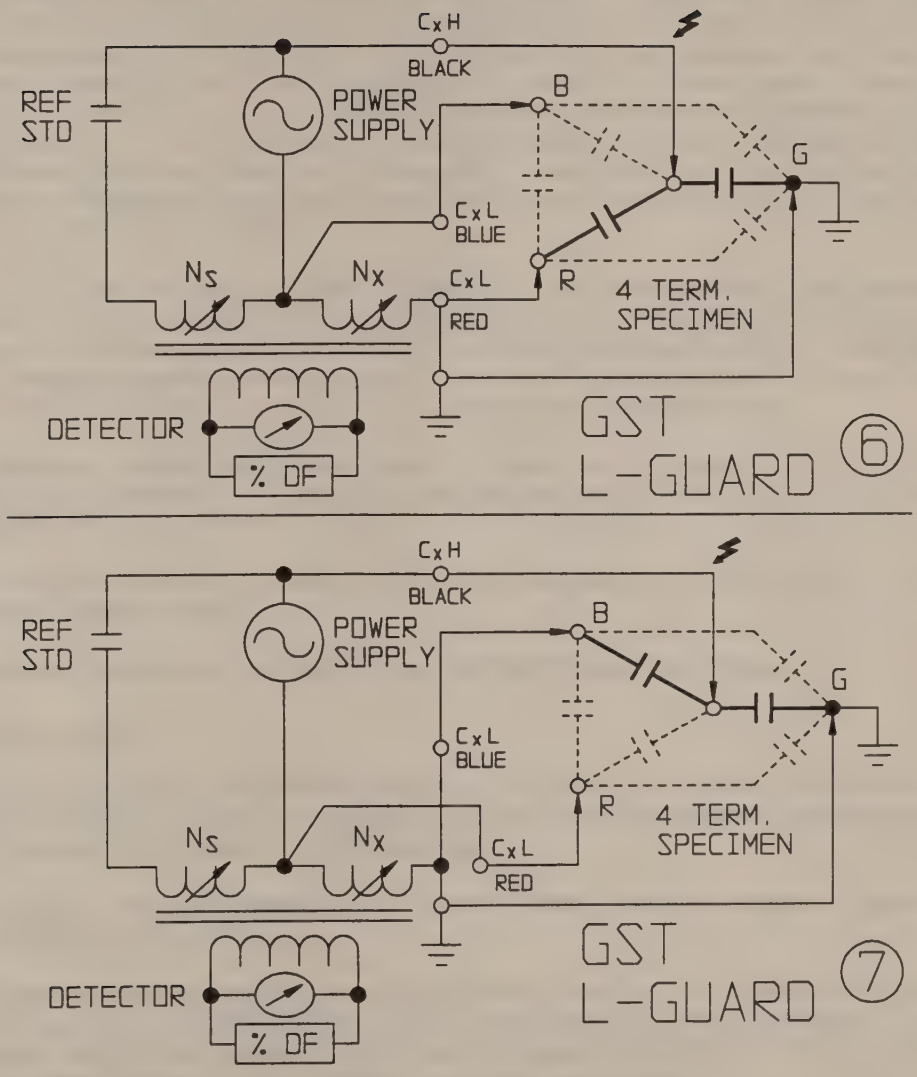


Figure 27: Connection for Four-Terminal Specimen, Test Modes 6 and 7

INTERPRETATION OF MEASUREMENTS

a. Significance of Capacitance and Dissipation Factor

A large percentage of electrical apparatus failures are due to a deteriorated condition of the insulation. Many of these failures can be anticipated by regular application of simple tests and with timely maintenance indicated by the tests. An insulation system or apparatus should not be condemned until it has been completely isolated, cleaned, or serviced and measurements compensated for temperature. The correct interpretation of capacitance and dissipation factor tests generally requires a knowledge of the apparatus construction and the characteristics of the particular types of insulation used.

Changes in the normal capacitance of an insulation indicate such abnormal conditions as the presence of a moisture layer, short circuits, or open circuits in the capacitance network. Dissipation factor measurements indicate the following conditions in the insulation of a wide range of electrical apparatus:

- Chemical deterioration due to time and temperature, including certain cases of acute deterioration caused by localized overheating.
- Contamination by water, carbon deposits, bad oil, dirt and other chemicals.
- Severe leakage through cracks and over surfaces.
- Ionization.

The interpretation of measurements is usually based on experience, recommendations of the manufacturer of the equipment being tested, and by observing these differences:

- Between measurements on the same unit after successive intervals of time.
- Between measurements on duplicate units or a similar part of one unit, tested under the same conditions around the same time, e.g., several identical transformers or one winding of a three-phase transformer tested separately.
- Between measurements made at different test voltages on one part of a unit; an increase in slope (tip-up) of a dissipation factor versus voltage curve at a given voltage is an indication of ionization commencing at that voltage.

An increase of dissipation factor above a typical value may indicate conditions such as those given in the previous paragraph, any of which may be general or localized in character. If the

dissipation factor varies significantly with voltage down to some voltage below which it is substantially constant, then ionization is indicated. If this extinction voltage is below the operating level, then ionization may progress in operation with consequent deterioration. Some increase of capacitance (increase in charging current) may also be observed above the extinction voltage because of the short circuiting of numerous voids by the ionization process.

An increase of dissipation factor accompanied by a marked increase in capacitance usually indicates excessive moisture in the insulation. Increase of dissipation factor alone may be caused by thermal deterioration or by contamination other than water.

Unless bushing and pothead surfaces, terminal boards, etc., are clean and dry, measured quantities may not necessarily apply to the volume of the insulation under test. Any leakage over terminal surfaces may add to the losses of the insulation itself and may, if excessive, give a false indication of its condition.

b. Dissipation Factor of Typical Apparatus Insulation

Values of insulation dissipation factor for various apparatus are shown in Table 1. These values may be useful in roughly indicating the range to be found in practice; however, the upper limits are not reliable service values. Dissipation factor has a direct advantage over an equivalent watts value since it is independent of the insulation thickness and area. The dielectric watts loss increases as the amount of insulation under test increases.

Table 1: DF of Typical Apparatus Insulation

Type Apparatus	% DF at 20°C
Oil-filled transformer: New, high-voltage (115 kV and up)	0.25 to 1.0
15 years old, high-voltage	0.75 to 1.5
Low-voltage, distribution type	1.5 to 5.0
Oil circuit breakers	0.5 to 2.0
Oil-paper cables, "solid" (up to 27.6 kV) new condition	0.5 to 1.5
Oil-paper cables, high-voltage oil-filled or pressurized	0.2 to 0.5
Rotating machine stator windings, 2.3 to 13.8 kV	2.0 to 8.0
Capacitors (discharge resistor out of circuit)	0.2 to 0.5
Bushings: Solid or dry	3.0 to 10.0
Compound-filled, up to 15 kV	5.0 to 10.0
Compound-filled, 15 to 46 kV	2.0 to 5.0
Oil-filled, below 110 kV	1.5 to 4.0
Oil-filled, above 110 kV and condenser type	0.3 to 3.0

c. Permittivity and % DF of Typical Insulating Materials

Typical values of permittivity (dielectric constant) k and 50/60 Hz dissipation factor of a few kinds of insulating materials (also water and ice) are given in Table 2.

Table 2: Permittivity of Typical Insulating Materials

Material	k	% DF at 20°C
Acetal resin (Delrin*)	3.7	0.5
Air	1.0	0.0
Askarels	4.2	0.4
Kraft paper, dry	2.2	0.6
Oil, transformer	2.2	0.02
Polyamide (Nomex*)	2.5	1.0
Polyester film (Mylar*)	3.0	0.3
Polyethylene	2.3	0.05
Polyamide film (Kapton*)	3.5	0.3
Polypropylene	2.2	0.05
Porcelain	7.0	2.0
Rubber	3.6	4.0
Silicone liquid	2.7	0.01
Varnished cambric, dry	4.4	1.0
Water**	80	100
Ice**	88	1.0 (0°C)

* Dupont registered trademark.

** Tests for moisture should not be made at freezing temperatures because of the 100 to 1 ratio difference of % dissipation factor between water and ice.

d. Significance of Temperature

Most insulation measurements have to be interpreted based on the temperature of the specimen. The dielectric losses of most insulation increase with temperature. In many cases, insulations have failed due to the cumulative effect of temperature, i.e., a rise in temperature causes a rise in dielectric loss which in turn causes a further rise in temperature, etc.

It is important to determine the dissipation factor-temperature characteristics of the insulation under test, at least in a typical unit of each design of apparatus. Otherwise, all tests of the same

specimen should be made, as nearly as practicable, at the same temperature. On transformers and similar apparatus, measurements during cooling (after factory heat-run or after service load) can provide the required temperature correction factors. For circuit breakers and other apparatus in which little heating occurs in service, measurements to determine correction factors can be made at different but constant ambient conditions.

To compare the dissipation factor value of tests made on the same or similar type apparatus at different temperatures, it is necessary to convert the value to a reference temperature base, usually 20°C (68°F). Tables of multipliers for use in converting dissipation factors at test temperatures to dissipation factors at 20°C are normally available from the apparatus manufacturer.

The test temperature for apparatus such as spare bushings, insulators, air or gas filled circuit breakers, and lightning arresters is normally assumed to be the same as the ambient temperature. For oil-filled circuit breakers and transformers the test temperature is assumed to be the same as the oil temperature. For installed bushings where the lower end is immersed in oil the test temperature lies somewhere between the oil and air temperature.

In practice, the test temperature is assumed to be the same as the ambient temperature for bushings installed in oil-filled circuit breakers and also for oil-filled transformers that have been out of service for approximately 12 hours. In transformers removed from service just prior to test, the temperature of the oil normally exceeds the ambient temperature. The bushing test temperature for this case can be assumed to be the midpoint between the oil and ambient temperatures.

Any sudden changes in ambient temperature will increase the measurement error since the temperature of the apparatus will lag the ambient temperature. The capacitance of dry insulation is not appreciably affected by temperature; however, in the case of wet insulation, there is a tendency for the capacitance to increase with temperature.

Dissipation factor-temperature characteristics, as well as dissipation factor measurements at a given temperature, may change with deterioration or damage of insulation. This suggests that any such change in temperature characteristics may be helpful in assessing deteriorated conditions.

Be careful making measurements below the freezing point of water. A crack in an insulator, for example, is easily detected if it contains a conducting film of water. When the water freezes, it becomes nonconducting, and the defect may not be revealed by the measurement, because ice has a volumetric resistivity approximately 100 times higher than that of water. Tests for the presence of

moisture in solids intended to be dry should not be made at freezing temperatures. Moisture in oil, or in oil-impregnated solids, has been found to be detectable in dissipation factor measurements at temperatures far below freezing, with no discontinuity in the measurements at the freezing point.

Insulating surfaces exposed to ambient weather conditions may also be affected by temperature. The surface temperature of the insulation specimen should be above and never below the ambient temperature to avoid the effects of condensation on the exposed insulating surfaces.

e. Significance of Humidity

The exposed surface of bushings may, under adverse relative humidity conditions, acquire a deposit of surface moisture which can have a significant effect on surface losses and consequently on the results of a dissipation factor test. This is particularly true if the porcelain surface of a bushing is at a temperature below ambient temperature (below dew point), because moisture will probably condense on the porcelain surface. Serious measurement errors may result even at a relative humidity below 50% when moisture condenses on a porcelain surface already contaminated with industrial chemical deposits.

It is important to note that an invisible thin surface film of moisture forms and dissipates rapidly on materials such as glazed porcelain which have negligible volume absorption. Equilibrium after a sudden wide change in relative humidity is usually attained within a matter of minutes. This, however, excludes thicker films which result from rain, fog, or dew point condensation.

Surface leakage errors can be minimized if dissipation factor measurements are made under conditions where the weather is clear and sunny and where the relative humidity does not exceed 80%. In general, best results are obtained if measurements are made during late morning through mid afternoon. Consideration should be given to the probability of moisture being deposited by rain or fog on equipment just prior to making any measurements.

f. Surface Leakage

Any leakage over the insulation surfaces of the specimen will be added to the losses in the volume insulation and may give a false impression as to the condition of the specimen. Even a bushing with a voltage rating much greater than the test voltage may be contaminated enough to cause a significant error. Surfaces of potheads, bushings, and insulators should be clean and dry when making a measurement.

It should be noted that a straight line plot of surface resistivity against relative humidity for an uncontaminated porcelain bushing

surface results in a decrease of one decade in resistivity for a nominal 15 percent increase in relative humidity and vice versa.

On bushings provided with a power factor or capacitance tap, the effect of leakage current over the surface of a porcelain bushing may be eliminated from the measurement by testing the bushing by the ungrounded specimen test (UST).

When testing bushings without a test tap under high humidity conditions, numerous companies have reported that the effects of surface leakage can be substantially minimized by cleaning and drying the porcelain surface and applying a very thin coat of Dow Corning #4 insulating grease (or equal) to the entire porcelain surface. When making a hot collar test, the grease is generally only applied to the porcelain surface on which the hot collar band is to be located and to that of one petticoat above and one below the hot collar band.

When testing potheads, bushings (without test tap), and insulators under unfavorable weather conditions, the dissipation factor reading may, at times, appear to be unstable and may vary slightly over a very short period of time. The variation is caused by such factors as the amount of surface exposure to sun or shade, variations in wind velocity, and gradual changes in ambient temperature and relative humidity. Similar bushings may have appreciably different dissipation factor values for the case where one bushing is located in the sun while the other is in the shade. A test made on the same bushing may have a different dissipation factor value between a morning and an afternoon reading. Due consideration must be given to variations in readings when tests are made under unfavorable weather conditions.

g. Electrostatic Interference

When tests are conducted in energized substations, the readings may be influenced by electrostatic interference currents resulting from the capacitance coupling between energized lines and bus work to the test specimen. In the shop or low-voltage substations the effects of electrostatic interference currents can be cancelled by taking normal and reverse voltage polarity readings. In high-voltage substations the effects of electrostatic interference currents can be cancelled by using the interference suppressor circuit. Normal and reverse voltage polarity readings should still be taken to cancel any residual interference currents. Trouble from magnetic fields encountered in high-voltage substations is very unlikely.

To counter the effects of severe electrostatic interference on the measurement, it may be necessary to disconnect the specimen from disconnect switches and bus work. Experience in making measurements will establish the particular equipment locations where it is necessary to break the connections. The related

disconnect switches, leads and bus work, if not energized, should be solidly grounded to minimize electrostatic coupling to the test set.

The measurement difficulty which is encountered when testing in the presence of interference depends not only upon the severity of the interference field but also on the capacitance and dissipation factor of the specimen. Unfavorable weather conditions such as high relative humidity, fog, overcast sky, and high wind velocity will increase the severity and variability of the interference field. The lower the specimen capacitance and its dissipation factor, the greater the difficulty, with possible reduction in accuracy, in making measurements. It is also possible that a negative dissipation factor reading may be obtained so it is necessary to observe the polarity sign for each reading. Specifically, it has been found that some difficulty may be expected when measuring capacitance by the GST test method in 230 through 550 kV low-profile switchyards when the capacitance value is less than 100 pF. This difficulty may be minimized considerably by:

- Using the maximum voltage of the test set if possible.
- Disconnecting and grounding as much bus work as possible from the specimen terminals.
- Making measurements on a day when the weather is sunny and clear, the relative humidity is less than 80%, the wind velocity is low, and the surface temperature of exposed insulation is above the ambient temperature.

Tests made by the UST method are less susceptible to interference pickup than are tests made by the GST method. In the UST test method, the capacitive coupled pickup current in the high-voltage circuit flows directly to ground after having passed through the high-voltage winding of the power supply transformer. In the GST test method the same pickup current, after passing through the high-voltage transformer winding, must pass through one of the bridge transformer-ratio measuring arms before reaching ground.

It is not generally recognized that when testing by the GST test method in the vicinity of other energized high-voltage circuits another form of interference is produced which may cause a change in the actual dissipation factor of the specimen. This interference is corona that may occur at the specimen high-voltage terminal, not as a result of the test voltage, but by intense fields between the specimen terminal and the adjacent energized high-voltage circuit. The corona loss resulting from this interference is added to the normal loss in the specimen, thereby increasing its dissipation factor. Since this type of interference is a loss related to the specimen in that particular environment, it cannot be eliminated from the test and cannot be considered as

an error in the measurement.

If the test set is energized from a portable generator when conducting tests in an energized substation, the readings may fluctuate over a significant range. This results from the frequency of test set voltage being out of synchronization with the electrostatic interference field. If it is not possible to synchronize the frequency of the two voltage systems, disconnect and ground as much bus work as possible from the specimen terminals. This will decrease both the interference pickup and the reading fluctuation.

h. Negative Dissipation Factor

In isolated cases, negative dissipation factors are encountered in the measurement of dielectric specimens of low capacitance. This condition is most likely to arise when making UST and GST L-GUARD measurements on specimens which have a capacitance value of a few hundred picofarads or less. Equipment such as bushings, circuit breakers, and low loss surge arresters fall into this category.

It is believed that the negative dissipation factor phenomenon is caused by a complex tee network of capacitance and resistance which exists within a piece of equipment. Error currents may flow into the measuring circuit in instances where phantom multiple terminals or a guard terminal appear in the measurement system. It is also believed that a negative dissipation factor may be produced by error currents flowing into a tee network as a result of space coupling from electrostatic interference fields.

The only time a negative dissipation factor has been observed is in cases where there is incomplete shielding of the measuring electrode or when the specimen itself is defective. The error is usually accentuated if tests are influenced by strong interference fields or are made under unfavorable weather conditions, especially a high relative humidity which increases surface leakage.

There appears to be no clear-cut way of knowing whether an error is significant or what remedies should be taken to overcome an error. The best advice is to avoid making measurements on equipment in locations where negative dissipation factors are known to present a problem when unfavorable weather conditions exist, especially high relative humidity. Make sure the surface of porcelain bushings are clean and dry to minimize the effects of surface leakage. Make sure all items such as wooden ladders or nylon ropes are removed from the equipment to be tested and are brought out of any electrostatic interference fields that could influence a measurement. Additional shielding around the low-voltage terminals of the specimen connected to the measuring and guarded leads of the test set should help to minimize this problem; however, this solution is generally not practical in the field.

TYPES OF APPARATUS

a. Transformers

The voltage rating of each winding under test must be considered and the test voltage selected accordingly. If neutral bushings are involved, their voltage rating must be considered in selecting the test voltage. Measurements should be made between each interwinding combination (or set of three-phase windings in a three-phase transformer) with all other windings grounded to the tank (UST test). Measurements should also be made between each winding (or set of three-phase windings) and ground with all other windings guarded (GST L-GUARD test). In a two-winding transformer, a measurement should also be made between each winding and ground with the remaining winding grounded (GST L-GROUND test). For a three-winding transformer, a measurement should also be made between each winding and ground with one remaining winding guarded and the second remaining winding grounded (GST L-GUARD test). This special test is used to isolate the interwindings. A final measurement should be made between all windings connected together and the ground tank. It is also desirable to test samples of the liquid insulation.

Figure 28 shows a typical setup for testing a two-winding transformer, Table 3 outlines the specific connections between the test set and two-winding transformer for each position of the UST/GST test mode selector switch. Table 4 specifies the connections for three-winding transformers. Note that each winding should be shorted on itself at its bushing terminals. It is recommended that the Measurement Intercheck calculations, specified on test connection charts of Tables 3 and 4 be performed to validate all measurements. The calculated intercheck values should agree with the direct measurement values within reasonable limits.

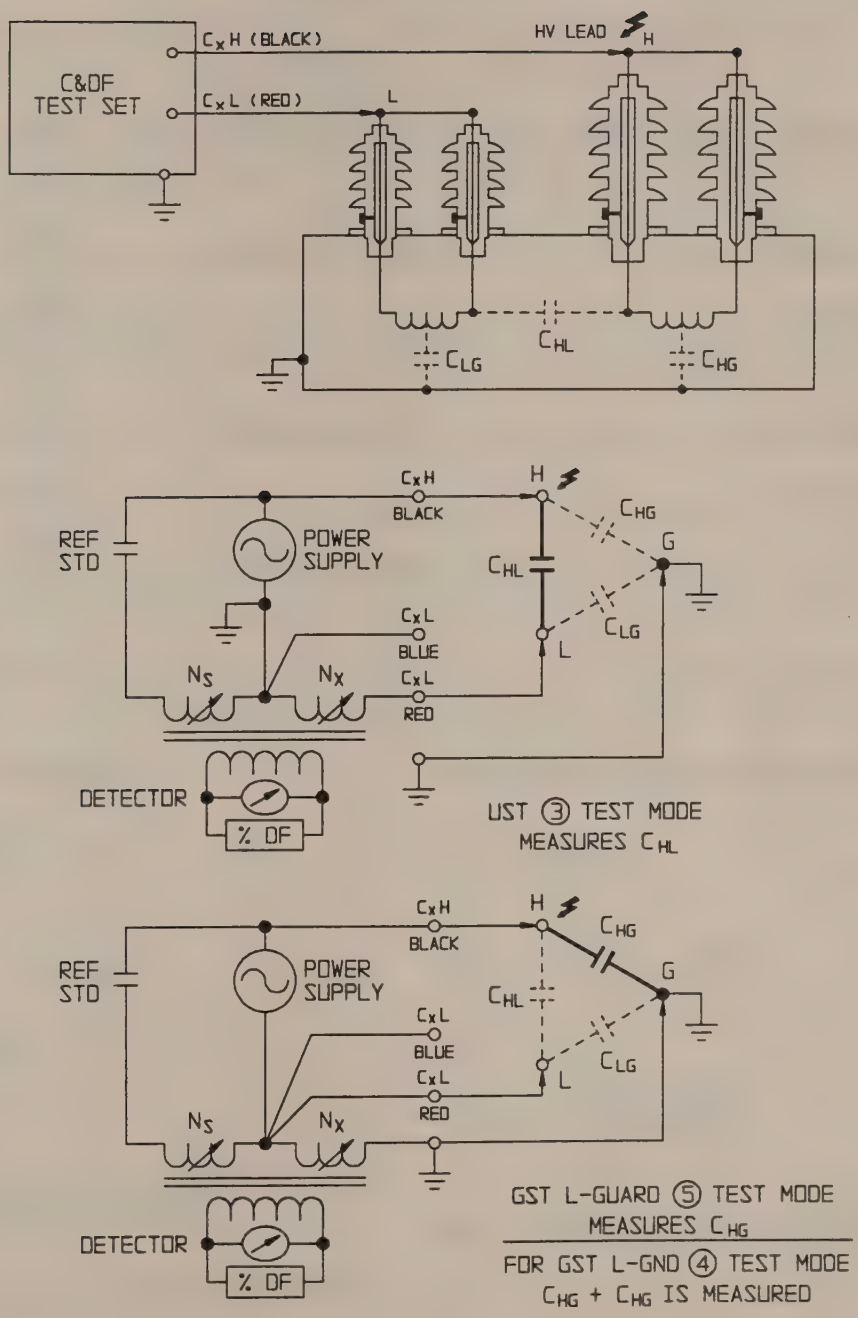
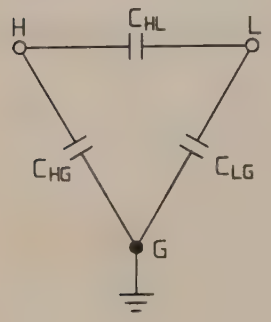


Figure 28: Two-Winding Transformer Tests

Table 3: Two-Winding Transformer Test Connections

Test No.	UST-GST Mode		Measures		Test Lead Conn			Remarks
	Test Type	Pos	Cap. Symbol	Bridge Symbol	⚡ Black	Red	Blue	
1	UST	3	C_{HL}	R	H	L	—	
2	GST L-GND	4	$C_{HL}+C_{HG}$	R+B+G	H	L	—	L grounded
3	GST L-GUARD	5	C_{HG}	G	H	L	—	L guarded
4	UST	3	C_{HL}	R	L	H	—	
5	GST L-GND	4	$C_{HL}+C_{LG}$	R+B+G	L	H	—	H grounded
6	GST L-GUARD	5	C_{LG}	G	L	H	—	H guarded
7	GST L-GND	4	$C_{HG}+C_{LG}$	R+B+G	H & L	—	—	
8								
9								
10								

Equivalent Circuit



H = High-voltage winding
L = Low-voltage winding
G = Ground

Note: Short each winding on itself.

Measurement Interchecks (Calculated)

$C_1 = C_2 - C_3$

$C_4 = C_5 - C_6$

$$DF_1 = \frac{C_2DF_2 - C_3DF_3}{C_2 - C_3}$$

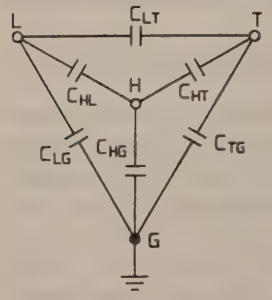
$$DF_4 = \frac{C_5DF_5 - C_6DF_6}{C_5 - C_6}$$

Note: Subscripts are test numbers.

Table 4: Three-Winding Transformer Test Connections

Test No.	UST-GST Mode		Measures		Test Lead Conn			Remarks
	Test Type	Pos	Cap. Symbol	Bridge Symbol	⚡ Black	Red	Blue	
1	UST	3	C_{HL}	R	H	L	T	T grounded
2	GST L-GUARD	6	$C_{HL}+C_{HG}$	R+G	H	L	T	T guarded L grounded
3	GST L-GUARD	5	C_{HG}	G	H	L	T	L & T guarded
4	UST	3	C_{LT}	R	L	T	H	H grounded
5	GST L-GUARD	6	$C_{LT}+C_{LG}$	R+G	L	T	H	H guarded T grounded
6	GST L-GUARD	5	C_{LG}	G	L	T	H	T & H guarded
7	UST	3	C_{HT}	R	T	H	L	L grounded
8	GST L-GUARD	6	$C_{HT}+C_{TG}$	R+G	T	H	L	L guarded H grounded
9	GST L-GUARD	5	C_{TG}	G	T	H	L	H & L guarded
10	GST L-GND	4	$C_{HG}+C_{LG}+C_{TG}$	R+B+G	H+L+T	—	—	

Equivalent Circuit



H = High-voltage winding
L = Low-voltage winding
G = ground

Note: Short each winding on itself.

Measurement Interchecks (Calculated)

$C_1 = C_2 - C_3$

$C_4 = C_5 - C_6$

$C_7 = C_8 - C_9$

$$DF_1 = \frac{C_2DF_2 - C_3DF_3}{C_2 - C_3}$$

$$DF_4 = \frac{C_5DF_5 - C_6DF_6}{C_5 - C_6}$$

$$DF_7 = \frac{C_8DF_8 - C_9DF_9}{C_8 - C_9}$$

Note: Subscripts are test numbers.

Increased dissipation factor values, in comparison with a previous test or tests on identical apparatus, may indicate some general condition such as contaminated oil. An increase in both dissipation factor and capacitance indicates that contamination is likely to be water. When the insulating liquid is being filtered or otherwise treated, repeated measurements on windings and the liquid will usually show whether good general conditions are being restored.

Oil oxidation and consequent sludging conditions have a marked effect on the dissipation factors of transformer windings. After such a condition has been remedied, (flushing down or other treatment) dissipation factor measurements are valuable in determining if the sludge removal has been effective.

Measurements on individual windings may vary due to differences in insulation materials and arrangements. However, large differences may indicate localized deterioration or damage. Careful consideration of the measurements on different combinations of windings should show in which particular path the trouble lies; for example, if a measurement between two windings has a high dissipation factor, and the measurements between each winding and ground, with the remaining winding guarded, gives a normal reading, then the trouble lies between the windings, perhaps in an insulating cylinder.

Bushings, if in poor condition, may have their losses masked by normal losses in the winding insulation. Therefore, separate tests should be applied to them. Temperature correcting curves for each design of transformer should be carefully established by measurement in factory or field and should be used to correct all measurements to a base temperature, usually 20°C.

b. Circuit Breakers

The most important insulation in medium and high-voltage outdoor power switch gear is that of the bushings themselves, the guide assembly, the lift rods, and, in the case of oil circuit breakers, the oil. Measurements should be made from each bushing terminal to the ground tank with the breaker open, and from each phase (each pair of phase bushing terminals) to the grounded tank with the breaker closed. When an individual bushing assembly is tested in each phase, the other bushing terminal in that phase should be guarded. It is also desirable to test samples of the liquid insulation.

The specific term "tank-loss index" has been developed to assist in evaluating the results of the open and closed oil circuit breaker tests. It is defined for each phase as the difference of the measured open circuit and closed circuit power, in watts. To obtain the open circuit value, the individual values measured on the two bushings of each phase must be summed. Tank-loss index may

have values ranging from positive to negative which will give an indication of the possible source of a problem. Positive indexes occur when the closed circuit values are larger than the sum of the open circuit values. Conversely, negative indexes occur when the closed circuit values are smaller than the sum of the open circuit values. The test results should be recorded in terms of equivalent 2.5 kV watts/milliwatts regardless of the test voltage used. To obtain watts from a measurement of capacitance and dissipation factor, refer to the conversion formulas.

Table 5, Oil Circuit Breaker Test Connections, outlines the specific connections between the test set and breaker as well as the series of measurements which should be performed on the breaker.

Comparison of tank-loss indexes taken when an oil circuit breaker is new and initially installed will give the general range of values to expect from a good unit. This practice also will avoid condemning a good unit as the result of the inherent design of a particular manufacturer that normally may show tank-loss indexes without the unit being defective or deteriorated.

The losses in an oil circuit breaker are different between an open circuit test and a closed circuit test because the voltage stress on the insulating members is disturbed differently. Table 6 summarizes what may be defective based upon the polarity of the tank-loss index. Once a particular section has given indications of deterioration, the test results should be verified by systematically isolating the suspected insulating member before disassembling the unit.

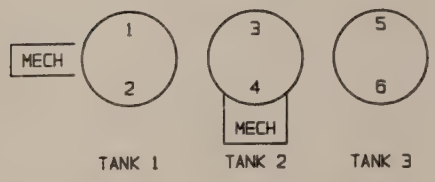
Oil circuit breakers are composed of many different materials each having its own temperature coefficient. For this reason it may be difficult to correct tank-loss indexes for a standard temperature. On this basis, an attempt should be made to conduct tests at approximately the same time of the year to minimize temperature variations. The measurements on the bushings, however, may readily be corrected to the base temperature, usually 20°C. Separate tests for measuring the losses in the bushings are described later.

Air and gas circuit breakers vary so much in construction that specific instructions and interpretation would be too lengthy. This section, however, does contain a detailed test connection chart (Table 7) outlining the normal series of measurements performed on a General Electric Type ATB Air-Blast Circuit Breaker.

Table 5: Oil Circuit Breaker Test Connections

Test No.	UST-GST Mode		Measures		Test Lead Conn			Remarks
	Test Type	Pos	Cap. Symbol	Bridge Symbol	⚡ Black	Red	Blue	
1	GST L-GUARD	5	C_{1G}	G	1	2	—	2 guarded
2	GST L-GUARD	5	C_{2G}	G	2	1	—	1 guarded
3	GST L-GUARD	5	C_{3G}	G	3	4	—	4 guarded
4	GST L-GUARD	5	C_{4G}	G	4	3	—	3 guarded
5	GST L-GUARD	5	C_{5G}	G	5	6	—	6 guarded
6	GST L-GUARD	5	C_{6G}	G	6	5	—	5 guarded
7	GST L-GND	4	$C_{1G}+C_{2G}$	R+B+G	1 or 2	—	—	
8	GST L-GND	4	$C_{3G}+C_{4G}$	R+B+G	3 or 4	—	—	
9	GST L-GND	4	$C_{5G}+C_{6G}$	R+B+G	5 or 6	—	—	
10								

Diagram



Note: Circuit breaker open: bushing tests (Test No. 1, 2, 3, 4, 5, 6). Circuit breaker closed: tank tests (Test No. 7, 8, 9).

Measurement Interchecks (Calculated)

$C_7 = C_1 + C_2$

$C_4 = C_3 + C_4$

$C_9 = C_5 + C_6$

$$DF_7 = \frac{C_1 DF_1 + C_2 DF_2}{C_1 + C_2}$$

$$DF_8 = \frac{C_3 DF_3 + C_4 DF_4}{C_3 + C_4}$$

$$DF_9 = \frac{C_5 DF_5 + C_6 DF_6}{C_5 + C_6}$$

Note: Subscripts are test numbers.

Table 6: Tank-Loss Index of Oil Circuit Breakers (Equivalent to 10 kV Losses)

Tank Loss Index	Test Remarks	Probable Problem	Insulation Rating
<±0.16 W	Normal results for both open CB tests	None	Good
>+0.16 W	Normal results for both open CB tests	1. Tank oil 2. Tank liner 3. Lift rod 4. Auxiliary contact insulation	Investigate
>-0.16 W	High losses for both open CB tests Closed CB test near normal	1. Cross guide assembly 2. Isolated cross guide 3. Contact assembly insulation 4. Lift rod upper section (moisture contaminated)	Investigate
<±0.16 W	Normal results for one open CB test Other has high losses	1. Bushing with high loss reading 2. Arc interruption assembly	Investigate
<±0.16 W	High losses for both open CB tests and closed CB test	1. Bushings 2. Arc interruption assembly 3. Tank oil 4. Tank liner 5. Lift rod 6. Auxiliary contact insulation 7. Cross guide assembly 8. Isolated cross guide 9. Contact assembly insulation	Investigate

Table 7: Circuit Breaker (Air-Blast Type) Test Connections

Test No.	UST-GST Mode		Measures		Test Lead Conn			Remarks
	Test Type	Pos	Cap. Symbol	Bridge Symbol	⚡ Black	Red	Blue	
1	UST	3	$C_2 + B_2$	R	D	F	A	A grounded
2	UST	2	$C_1+B_1+I_1$	B	D	F	A	F grounded
3	UST	1	C_2+B_2+ $C_1+B_1+I_1$	R&B	D	F	A	
4	GST L-GUARD	5	R(or $R+I_3$)	G	D	F	A	F&A guarded
5*	GST L-GUARD	6	I_2+T	R&G	A	F	D	D guarded F grounded

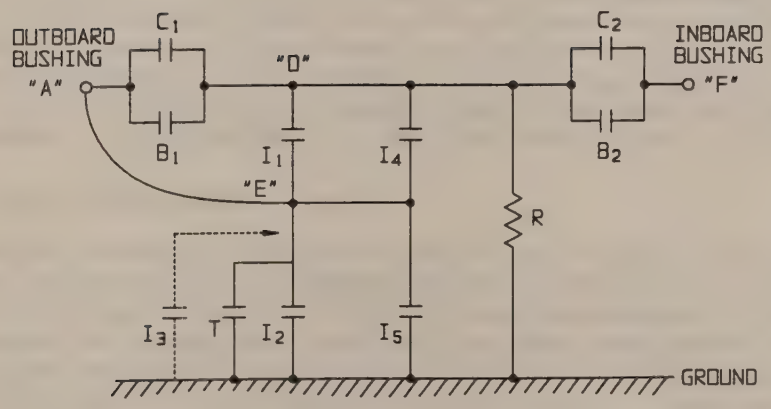
* Test performed only on units with current transformer.

Measurement Intercheck

$$C_1 = C_3 - C_2$$

$$DF_1 = \frac{C_3 DF_3 - C_2 DF_2}{C_3 - C_2}$$

Note: Subscripts are test numbers.



B_1 and B_2 Entrance bushings
C_1 and C_2 Grading capacitors
I_1 Upper insulator
I_2 Lower insulator
I_3 Insulator for units without current transformer
R Glass fiber air supply tube, oper. rods and wood tie rods
T Current transformer insulation
I_4 and I_5 Protective glass fiber tube which encloses R tube is slit at "E" with metal guard ring

c. Bushings

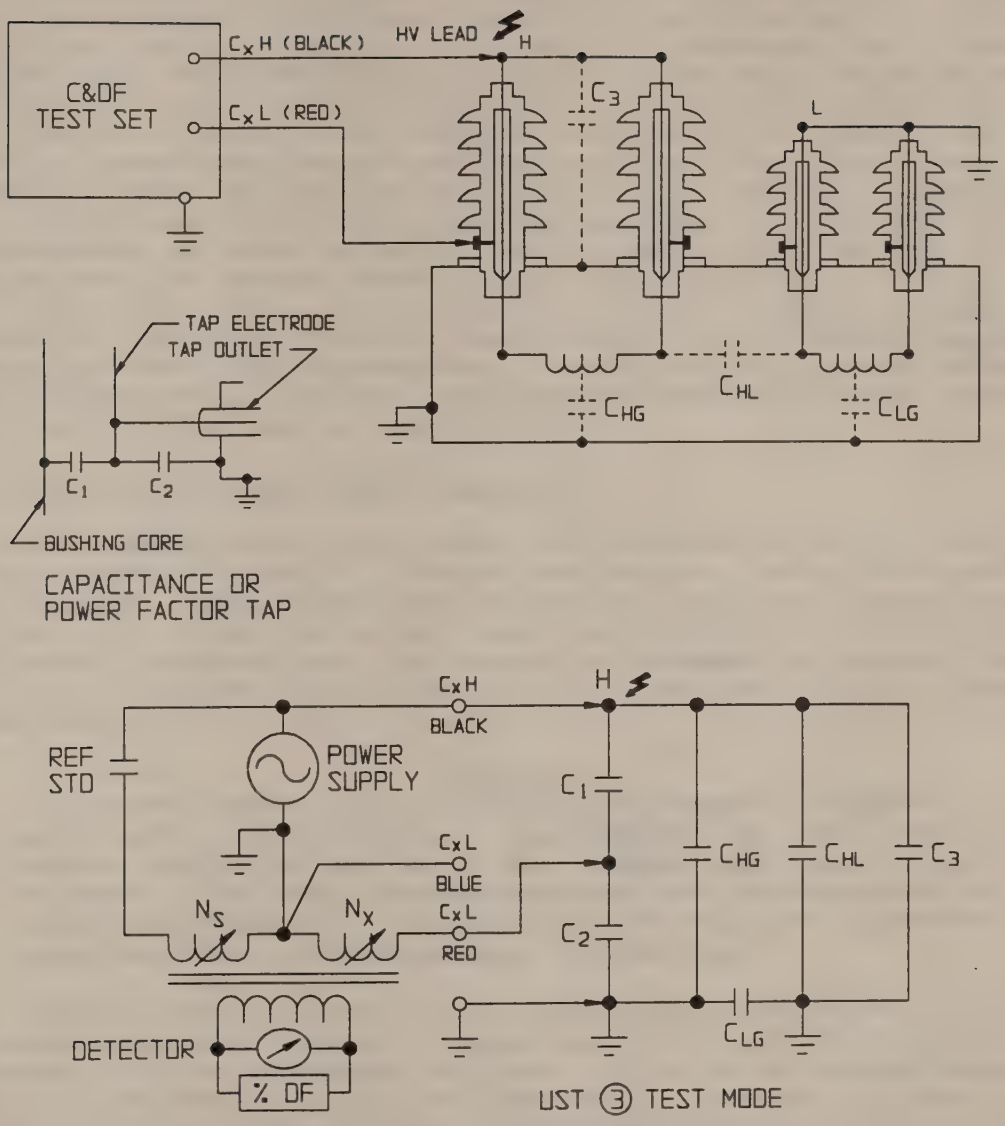
All modern bushings rated 23 kV and higher have a power factor or a capacitance tap which permits dissipation factor testing of the bushing while it is in place on the apparatus without disconnecting any leads to the bushing. The dissipation factor is measured by the ungrounded specimen test (UST) which eliminates the influence of transformer winding insulation, breaker arc-interrupters, or support structures which are connected to the bushing terminal. The effects of stray capacitance between the bushing terminal and ground as well as surface leakage over the porcelain are also eliminated from the measurement. The UST method measures only the bushing and is not appreciably affected by conditions external to the bushing.

Figure 29 shows the test connections between the test set and bushing when using the UST test mode. Connect the high-voltage lead (black boot) to the terminal at the top of the bushing and the low-voltage lead (red boot) to the power factor tap. Ground the apparatus tank. The tap is normally grounded through a spring and it is necessary, when making measurements, to remove the plug which seals and grounds the tap. Use the UST 3 test mode setting.

The UST test also can be used for making measurements on bushings which have provisions for flange isolation. The normal method of isolating the flange from the apparatus cover is to use insulating gaskets between the flange and cover and insulating bushings on all but one of the bolts securing the mounting flange to the cover. During normal operation, the flange is grounded by a single metal bolt; however, when testing the bushing, this bolt is removed. The measurement is identical to that when testing bushings which have a power factor tap except that the low-voltage lead, red in this case, is connected to the isolated bushing flange.

Hot Collar Test

The dielectric losses through the various sections of any bushing or pothead can be investigated by means of a hot collar test which generates localized high-voltage stresses. This is accomplished by using a conductive hot collar band designed to fit closely to the porcelain surface, usually directly under the top petticoat, and applying a high voltage to the band. The center conductor of the bushing is grounded. This test provides a measurement of the losses in the section directly beneath the collar and is especially effective in detecting conditions such as voids in compound filled bushings or moisture penetration since the insulation can be subjected to a higher voltage gradient than can be obtained with the normal bushing tests.



Measures main bushing insulation C_1

C_{HG}, C_{HL}, and C_3 shunt power supply, therefore no influence on measurement

C_2 shunts bridge winding, therefore negligible influence if less than 5000 pF

Figure 29: UST Test on Transformer Bushing

This method is also useful in detecting faults within condenser layers in condenser-type bushings and in checking the oil level of oil-filled bushings after a pattern of readings for a normal bushing has been established. If an abnormal capacitance or dissipation factor reading is obtained, the test should be repeated with the hot collar band wrapped around the porcelain surface directly under the second petticoat rather than the first. If necessary, move the band further down on the bushing to determine the depth that the fault has progressed. The hot collar measurements are made by normal GST L-GROUND test method and the bushing need not be disconnected from other components or circuits. Make sure that the collar band is drawn tightly around the porcelain bushing to ensure a good contact and eliminate possible corona problems at the interface. Refer to Application Notes on the Significance of Humidity and Surface Leakage if tests are made under unfavorable weather conditions.

Power Factor or Capacitance Tap Test

Insulation tests on a power factor or capacitance tap of a bushing are performed by the GST L-GUARD test method. For this test the high-voltage lead is connected to the tap, the low-voltage lead to the bushing center conductor, and the bushing flange grounded. This method measures only the insulation between the tap and ground and is not appreciably effected by connections to the bushing center conductor.

CAUTION

The power factor tap is normally designed to withstand only about 500 V while a capacitance tap may have a normal rating of 2.5 to 5 kV. Before applying a test voltage to the tap, the maximum safe test voltage must be known and observed. An excessive voltage may puncture the insulation and render the tap useless.

Some bushings do not have a power factor or capacitance tap or an isolated mounting flange. These bushings must be electrically isolated from the apparatus for test. This can be accomplished by removing the metal bolts and temporarily replacing them with insulated bolts. The insulating gasket between the bushing flange and apparatus cover will normally provide sufficient insulation so that a UST type measurement can be made on the bushing in the same manner as for a bushing which has provisions for flange isolation. Verify isolation with an ohmmeter.

Evaluation of Test Results

Interpretation of capacitance and dissipation factor measurements on a bushing requires a knowledge of the bushing construction since each type bushing has its own peculiar characteristics. For example, an increase in dissipation factor in an oil-filled bushing may indicate that the oil is contaminated, whereas an increase in

both dissipation factor and capacitance indicates that the contamination is likely to be water. For a condenser type bushing which has shorted layers, the capacitance value will increase, whereas the dissipation factor value may be the same in comparison with previous tests.

Except for the specific purpose of investigating surface leakage, the exposed insulation surface of the bushing should be clean and dry to prevent surface leakage from influencing the measurement. The effects of surface leakage are eliminated from the measurement when testing by the UST test method.

Temperature correction curves for each design of bushing should be carefully established by measurement and all measurements should be temperature corrected to a base temperature, usually 20°C. The temperature measurement should be based on that at the bushing surface. The air temperature should also be recorded. When testing a bushing by the grounded specimen method, the surface of the bushing should be at a temperature above the dew point to avoid moisture condensation.

d. Rotating Machines

The main purpose of capacitance and dissipation factor tests on rotating machines is to assess the extent of void formation within the winding insulation and the resulting damage to the insulation structure due to ionization (partial discharge) in the voids. An overall measurement on a winding will also give an indication of the inherent dissipation factor of the winding insulation and will reveal potential problems due to deterioration, contamination, or moisture penetration.

A power factor (dissipation factor) tip-up test is a widely used maintenance test in evaluating the extent of insulation deterioration caused by ionization. In this test, the dissipation factor is measured at two different voltages, the first low enough so that no ionization occurs (normally 25% of rated line-to-ground voltage), the second at rated line to ground voltage or slightly above rated voltage. The tip-up value is obtained by subtracting the value of the dissipation factor measured at the lower test voltage from that measured at the higher test voltage. When the dissipation factor increases significantly above a certain voltage, it is evident that ionization is active and producing some loss. An increase in dissipation factor above a certain voltage is a guide to the rate at which ionization is occurring and gives guidance as to how the ionization action may be expected to accelerate. If voids are short-circuited when ionization occurs, some increase of capacitance with voltage may also result. Any forecast of remaining useful life must be based upon knowledge of the resistance of the particular insulation to ionization.

In general, the coils nearest the line terminals and operating at

the highest voltage to ground are most affected by ionization. The reliable life remaining in a winding can often be extended by obtaining dissipation factor versus voltage curves on all coils, replacing only the worst, and regrouping them so that the coils with the least increase of dissipation factor, and preferably lower value of dissipation factor, are nearest the line terminals. Considerable extension of winding life can also be realized in many cases by measuring dissipation factor versus voltage on groups of coils without removal and rearranging the line and neutral connections accordingly. This can be done several times in a lifetime so that the coils are evenly deteriorated.

An overall measurement on a rotor or stator winding is made on the insulation between the winding and ground. In the case of three-phase stator windings, where the connection between the winding phases and neutral can be conveniently opened, additional measurements are also made on the interwinding or phase-to-phase insulation. When a tip-up test is made on a complete phase winding, only the average value is measured; an isolated section having an abnormally high tip-up may be completely masked.

Table 8 shows the specific connections between the test set and a typical generator three-phase stator winding as well as the routine series of measurements performed on the windings. It is assumed that the connection between the winding phases and also neutral are opened. The phase-to-ground insulation tests are made by the GST test method, whereas, the phase-to-phase tests are made by the UST test method.

When testing large generator windings which have a very high value of capacitance per phase, the maximum specimen capacitance measurable at a particular test voltage may be limited due to the thermal rating of the power supply transformer (refer to Section 3, Specifications). For this case tests will have to be made at a reduced voltage level.

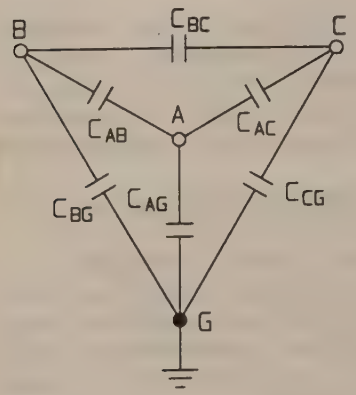
The temperature of the windings should be above and never below the ambient temperature to avoid the effects of moisture condensation on the exposed insulating surface. Temperature measurements when using temperature correction curves should be based on that at the winding surface.

Avoid prolonged exposure to high humidity conditions before testing because such exposure may result in moisture absorption in the insulating materials. It is desirable to make tests on the winding insulation shortly after shutdown.

Table 8: Three-Phase Generator Stator Test Connections

Test No.	UST-GST Mode		Measures		Test Lead Conn			Remarks
	Test Type	Pos	Cap. Symbol	Bridge Symbol	⚡ Black	Red	Blue	
1	UST	3	C_{AB}	R	A	B	C	C grounded
2	GST L-GUARD	5	C_{AG}	G	A	B	C	B&C guarded
3	UST	3	C_{BC}	R	B	C	A	A grounded
4	GST L-GUARD	5	C_{BG}	G	B	C	A	C&A guarded
5	UST	3	C_{AC}	R	C	A	B	B grounded
6	GST L-GUARD	5	C_{CG}	G	C	A	B	A&B guarded
7	GST L-GROUND	4	$C_{AG}+C_{BG}+C_{CG}$	R+B+G	A+B+C	—	—	may exceed test set kVA rating

Equivalent Circuit



Remarks

A = Phase A winding
B = Phase B winding
C = Phase C winding
G = Ground

Note: Short each winding on itself.

e. Cables

Cables rated for operation at 5 kV and above are usually shielded by a metal cable sheath. Measurements for this type cable are made by the GST L-GROUND test method and are confined to the insulation between the conductor and the sheath. The high-voltage lead is connected to the cable conductor and the cable sheath solidly connected to the same grounding system as the test set.

When testing three conductor cables which have a single metal cable sheath, UST tests should be made between each conductor combination with the remaining cable grounded. A second set of tests should be made between each conductor and ground with the remaining two conductors guarded (GST L-GROUND test). A third test should be made between all conductors connected together and ground (GST test). This test procedure is similar to that when testing three winding transformers.

The test set measures the average dissipation factor of the cable; therefore, if a long length of cable is measured, an isolated section of cable having an abnormally high dissipation factor may be completely masked and have no significant effect on the average value. Thus, the ability to detect localized defects will diminish as the cable length increases. Tests on long lengths of cable give a good indication of the inherent dissipation factor of the insulation and when compared with previous tests or measurements on similar cable may reveal potential problems due to general deterioration, contamination, or moisture penetration.

Cables are inherently of relatively high capacitances per unit length (typically 0.5 μF per phase per mile) so that for long lengths the kVA capacity of the test set power supply may be exceeded. Refer to Section 3, Specifications, for maximum specimen capacitance measurable at a particular test voltage.

f. Surge (Lightning) Arresters

A complete test on a surge arrester involves impulse and overvoltage testing as well as a test for power loss at a specified test voltage using normal 50/60 Hz operating frequency. Impulse and overvoltage testing is not generally performed in the field since it involves a large amount of test equipment that is not easily transportable. Experience has demonstrated that the measurement of power loss is an effective method of evaluating the integrity of an arrester and isolating potential failure hazards. This test reveals conditions which could affect the protective functions of the arrester, such as: the presence of moisture, salt deposits, corrosion, cracked porcelain, open shunt resistors, defective pre-ionizing elements, and defective gaps.

To evaluate the insulation integrity of an arrester, measure the power loss (watts-loss or dissipation factor) at a specified voltage and compare it with previous measurements on the same or similar arrester. Measurements on a surge arrester should always be performed at the same or recommended test voltage since nonlinear elements may be built into an arrester. When using this test set, all measurements should normally be made at 10 kV. Except for the specific purpose of investigating surface leakage, the exposed insulation surface of an arrester should be clean and dry to prevent leakage from influencing the measurements.

Some types of arresters show a substantial temperature dependence, while others show very little dependence. Temperature correction curves for each arrester design should be carefully established by measurement, and all measurements should be temperature corrected to a base temperature, usually 20°C. The temperature measurement should be based on that at the arrester surface. The air temperature should also be recorded. The surface of the arrester should be at a temperature above the dew point to avoid moisture condensation.

WARNING

Exercise extreme care when handling arresters suspected of being damaged, since dangerously high gas pressures can build up within a sealed unit.

It is recommended that tests be made on individual arrester units rather than on a complete multi-unit arrester stack. A single arrester unit can be tested by the normal ungrounded specimen test (UST) in the shop; however, it can only be tested by the grounded specimen test (GST) when mounted on a support structure in the field. Table 9 shows the recommended test procedure for testing installed multi-unit arrester stacks. When testing in the field, disconnect the related high-voltage bus from the arrester.

Surge arresters are often rated on the basis of watts loss. To obtain the equivalent 10 kV watts loss from a measurement of capacitance and dissipation factor, perform the following calculations:

$$\text{Watts loss} = C_{pF} \times \%DF \times 377 \times 10^{-6} \text{ (for 60 Hz)}$$
$$\text{Watts loss} = C_{pF} \times \%DF \times 314 \times 10^{-6} \text{ (for 50 Hz)}$$

where: C_{pF} = capacitance in picofarads
%DF = percent dissipation factor

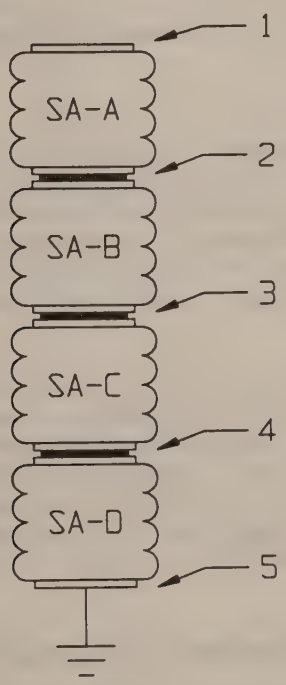
NOTE

Capacitance, dissipation factor, power factor, watts at 10 kV, current, and current at 10 kV can all be read directly from the test set. These formulas are provided for informational purposes only.

Table 9: Surge Arrester Test Connections

Test No.	UST-GST Mode		Measures		Test Lead Conn			Remarks
	Test Type	Pos	Surge Arrester Symbol	Bridge Symbol	⚡ Black	Red	Blue	
1	UST	2	SA-A	B	2	3	1	Red lead grounded
2	UST	3	SA-B	R	2	3	1	Blue lead grounded
3	UST	3	SA-C	R	4	3	—	—
4	GST L-GUARD	5	SA-D	G	4	3	—	Red lead guarded

Note: All tests normally made at 10 kV.



Typical Multi-Unit Arrester Stack

In some cases, where limited test data are recorded, it may be desirable to convert equivalent 10 kV watts loss to equivalent 2.5 kV watts loss and vice versa. The conversion can be made using the following formula. Keep in mind that the relationship is true only when testing arresters which have a linear response below a 10 kV test voltage.

$$\text{Watts loss @ 2.5 kV} = \frac{\text{Watts loss @ 10 kV}}{16}$$

An increase in dissipation factor or watts loss values compared with a previous test or tests on identical arresters under the same conditions may indicate:

- Contamination by moisture
- Contamination by salt deposits
- Cracked porcelain housing
- Corroded gaps.

A decrease in dissipation factor or watts loss values may indicate:

- Open shunt resistors
- Defective pre-ionizing elements.

g. Liquids

To measure the dissipation factor of insulating liquids, a special test cell such as the Biddle Catalog No. 670511 Oil Test Cell is required. It is constructed with electrodes which form the plates of a capacitor and the liquid constitutes the dielectric. The test cell is a three-terminal type with a guard electrode to avoid measuring fringe effects and the insulation for the electrode supports.

When samples of insulating liquid are tested, the specimen capacitance is used for determining the dielectric constant (permittivity) of the insulating liquid. The ratio of the test cell capacitance measured when empty (air dielectric) to the test cell capacitance measured when filled (liquid dielectric) is the value of dielectric constant of the liquid. Instructions for the use of the Oil Test Cell are contained in Instruction Manual AVTM670511.

h. Miscellaneous Assemblies and Components

When an apparatus is dismantled to locate internal trouble and make repairs, dissipation factor measurements can be valuable in detecting damaged areas of insulation to such parts as wood or fiberglass lift-rods, guides or support members. Sometimes existing metal parts can be used as the electrodes between which measurements can be made. Sometimes it will be necessary to

provide electrodes. Conductive collars, can be used; aluminum foil also works well. Whenever conducting material is used, ensure that intimate contact is made with the critical areas of the insulation. Petroleum jelly or Dow Corning #4 insulating grease applied at the interface surface often helps to obtain better physical contact.

It may sometimes be necessary to separate volume losses from surface losses by providing a third (guard) terminal on or within the specimen insulation system. For example, an insulating tube formed over a metal rod may be tested for internal damage in the insulation. A conductive band (or foil) is applied near the center of the insulating tube with additional conductive (guard) bands on each side, separated from the center band by enough clean insulation to withstand the intended test voltage. With the metal rod grounded, the test set will measure the capacitance and dissipation factor of the volume of insulation between the center conductive band (high-voltage) and the metal rod. Figure 30 shows a typical test setup.

Comparisons between dissipation factors of suspected areas and components against similar parts which can be assumed to be in good condition are of prime importance in analyzing insulation components. Dissipation factor voltage measurements can indicate the presence of ionization in a component by a sudden tip-up of dissipation factor as the test voltage is increased. Delaminations within a material can also be detected in this way. Avoid overstressing component insulation by indiscriminate use of the available test voltage. Consider the voltage on the component under normal operating conditions.

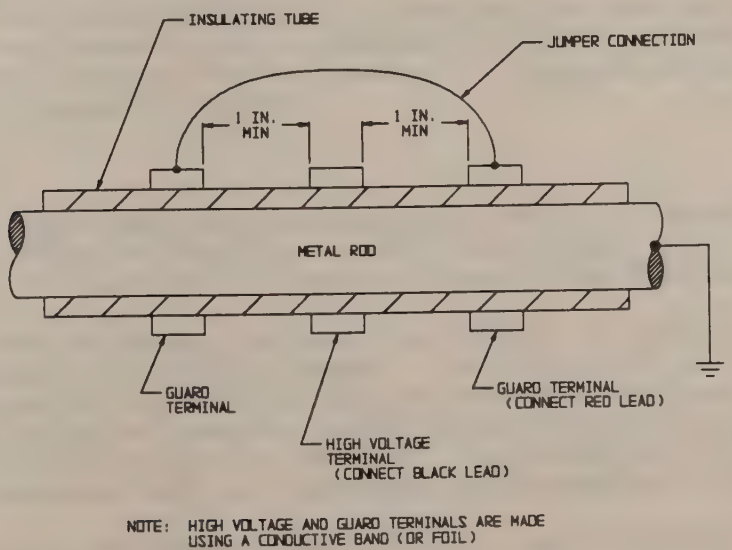

INSULATING TUBE
JUMPER CONNECTION
1 IN. MIN
1 IN. MIN
METAL ROD
GUARD TERMINAL
HIGH VOLTAGE TERMINAL (CONNECT BLACK LEAD)
GUARD TERMINAL (CONNECT RED LEAD)
NOTE: HIGH VOLTAGE AND GUARD TERMINALS ARE MADE USING A CONDUCTIVE BAND (OR FOIL)

Figure 30: GST L-GUARD Test on Insulated Tube Covering Metal Rod

Section 7

Maintenance and Calibration

MAINTENANCE

Maintenance should be performed only by qualified persons familiar with the hazards involved with high-voltage test equipment. Read and understand Section 2, Safety, before performing any service.

Routine maintenance is all that is required for these test sets. The cables and connector panel should be inspected frequently to be sure all connections are tight and all ground connections intact. The appearance of the test set can be maintained by occasional cleaning of the case, panel and cable assemblies.

The outside of the carrying case can be cleaned with detergent and water. Dry with a clean, dry cloth.

The control panel can be cleaned with a cloth dampened with detergent and water. Do not allow water to penetrate panel holes, because damage to components on the underside may result. A household all-purpose spray cleaner can be used to clean the panel. Polish with a soft, dry cloth, taking care not to scratch the display screen cover.

The cables and mating panel receptacles can be cleaned with isopropyl or denatured alcohol applied with a clean cloth.

Contamination of some parts of the high-voltage circuit, in particular the high-voltage cable terminations and its mating panel receptacle, may show up as a residual DF meter reading. Cleaning of these sensitive parts will remove the leakage paths which cause the unwanted leakage current.

CALIBRATION

A complete operation and calibration check as described in the following should be made at least once every year. This will ensure that the test set is functioning and calibrated properly.

To perform the following calibration checks, loosen and remove the screws securing the control panel. Set the unit on a bench with the latch side down. Then slide the control panel out of the case a few inches to allow access to the push-button switch situated on the right side near the PC boards. Calibration potentiometers, labeled R1 through R10, are mounted on the middle PC board.

1. The analog PCB potentiometers will be precisely set in this step and a complete overall Test/Calibration sequence performed on the control unit. The control unit must be allowed to warm-up for at least 2 minutes before attempting to

adjust the potentiometers.

2. To initiate the Test/Calibration sequence, which is controlled by the microprocessor, press the MENU button then go to the Second Menu Screen. Enter CALIBRATION CHECK.

3. Follow Table 10 Test/Calibration sequence, steps 1 through 19 to check Analog PCB operation and to adjust potentiometers precisely. Table 10 also contains an abbreviated troubleshooting guide in the event of a malfunction. Press the push-button switch located at the bottom right side of the microprocessor PCB when ready to advance to the next step.

4. Table 10 steps 20 through 23 check both Analog and Relay PCB operation. Step 24 initiates an automatic sequence of 73 self check steps on the Relay PCB. The entire self-check sequence is performed within 38 seconds. Countdown appears on the graphic screen.

For an approved calibration check there should be no diagnostic error messages appearing on the LCD at the end of countdown (00). Absence of an error message indicates all measurements within tolerance.

A diagnostic error for the Relay PCB will appear on the LCD in the following typical format.

```
DIAGNOSTIC ERROR TEST #03     12
DIAGNOSTIC ERROR TEST #06     08
DIAGNOSTIC ERROR TEST #18     22
DIAGNOSTIC ERROR TEST #56     14
```

The first number indicates the Table 11 test number step.
The second number indicates the number of bits error measured by the A/D converter (1 bit = 4.8828 mV).

Table 11 indicates the instrument setup for each of the 73 self-check steps as well as the possible faulty component for a malfunction on the Relay PCB.

Table 12 tabulates the function of all relays (K numbers) and CMOS switches (U numbers).

5. Switch MAIN breaker OFF, then disconnect all cables to the control unit. This completes Preliminary Operation and Calibration Checks.

Table 10: Analog PCB Calibration Checks

Test/Calibration Check Sequence	Adjustment/Check Display Indication	Malfunction Checks or Possible Cause
(1) "O Cross" Detector Check	Will skip to next step if check is OK Displays "No Crossing Detector" for malfunction	Recheck +15 V, -15 V, +10 V, -10 V and +5 V supply voltages Check for +5 V 1/2 cycle square wave at TP35
(2) "Phase Locked Loop" Check	Will skip to next step if check is OK Displays "No Phase Locked Loop" for malfunction	Voltage at TP36 will be +5V if locked and <-0.6 V if unlocked Defective U42 or U50
(3) A/D Offset Adjust R9	Adjust R9 to between -9.995 and -10.004 (should trigger between H and L limits)	Defective U3, U11, U10, U15, U12
(4) A/D Gain Adjust R10	Adjust R10 to between 9.990 and 10.000 (should trigger between H and L limits)	Defective U3, U11, U10, U15, U12
(5) A/D Zero Check	Should be 0.000 ±0.020	Defective U3, U11, U10, U15
(6) C DAC Offset Adjust R7	Adjust R7 to 0.000 ±0.005	Defective U 44, U48, U32, U46, U47, U49
(7) C DAC Gain Adjust R3	Adjust R3 to 9.982 ±0.010	Defective U44, U48, U32, U3, U46, U47, U45
(8) C DAC Minus Gain Check	Should be -9.982 ±0.010	Defective U44, U48, U32, U3, U46, U47, U45
(9) DF DAC Offset Adjust R8	Adjust R8 to 0.000 ±0.005	Defective U44, U32, U3, U52, U53, U54, U55
(10) DF DAC Gain Adjust R4	Adjust R4 to 9.982 ±0.010	Defective U44, U32, U3, U52, U53, U54, U55
(11) DF DAC Minus Gain Check	Should be -9.982 ±0.010	Defective U44, U32, U3, U52, U53, U54, U55
(12) C Supp DAC Offset Adjust R6	Adjust R6 to 0.000 ±0.005	Defective U51, U32, U3, U37, U38, U39, U40
(13) C Supp DAC Gain Check	Should be 9.689 ±0.20	Defective U51, U32, U3, U37, U38, U39, U40
(14) C Supp DAC Minus Gain Check	Should be -9.689 ±0.20	Defective U51, U32, U3, U37, U38, U39, U40
(15) DF Supp DAC Offset Adjust R5	Adjust R5 to 0.000 ±0.005	Defective U51, U32, U3, U61, U62, U63, U64
(16) DF Supp DAC Gain Check	Should be 9.689 ±0.20	Defective U51, U32, U3, U61, U62, U63, U64
(17) DF Supp DAC Minus Gain Check	Should be -9.689 ±0.20	Defective U51, U32, U3, U61, U62, U63, U64

Table 10: Analog PCB Calibration Checks (contd)

Test/Calibration Check Sequence	Adjustment/Check Display Indication	Malfunction Checks or Possible Cause
(18) Voltage Channel Check	Should be 8.000 ±0.050	Check for 10.0 V P-P Square Wave at TP4 Defective U33, U4, U3, u1, U6, U7, U12
(19) Current Channel Check	Should be 8.000 ± 0.050	Defective U33, U5, U3, U1, U6, U7, U12
(20) Filter Phase Adjust R2	Adjust R2 to 0.000 ±0.020	Defective U3, U17, U23, U44, U60
(21) C Phase Rectifier Check	Should be -1.150 ±0.30	Defective U3, U17, U23, U44, U60
(22) DF Phase Rectifier Adjust R1	Adjust R1 to 0.000 ±0.020	Defective U3, U17, u23, U44, U60
(23) DF Phase Rectifier Check	Should be -1.150 ±0.30	Defective U3, U17, U23, U44, U60
(24) Overall check of complete analog PCB and relay PCB	Instrument makes 73 diagnostic self-checks within 38 seconds. At end of countdown, there should be no diagnostic error.	Refer to Table 11 for explanation of relay PCB test number and magnitude of error.

Table 11: Relay PCB Calibration Checks

Test No.	Meas Chan C/DF	N_x Winding (Turns)	N_s Winding (Turns)	Multiplier DAC & Range Settings	Analog U12 Gain	Error Allowed A/D Bits	Possible Defective Component
01	C	0T	0T	All 4 DACs set to "0"	10	10	See steps 20 - 23 of Table 10
02	C	10T	10T	All 4 DACs set to "0"	10	10	K11, K34, U19, U23
03	C	10T	10 x 1T	All 4 DACs set to "0"	10	10	K11, K54, U19, U26
04	C	100T	100T	All 4 DACs set to "0"	10	10	K12, K23, U19, U21
05	C	100T	10 x 10T	All 4 DACs set to "0"	10	10	K12, K43, U19, U24
06	C	1T	1T	All 4 DACs set to "0"	10	10	K10, K45, U19, U25
07	C	1T	1T	All 4 DACs set to "0"	100	102	K10, K45, U19, U25
08	C	1T	2T	"C DAC" -0.5 FS	100	61	K10, K19, U25, U45
09	C	1T	0T	"C DAC" +0.5 FS	100	61	K10, K19, U25, U44
				"C", "DF", "DF SUPP" DACs set to "0" (steps 10-12)			
10	C	0T	0T	C SUPP DAC +FS range 1	10	82	U7, U8, U9
11	C	0T	0T	C SUPP DAC +FS range 2	1	82	K60, U27
12	C	0T	0T	C SUPP DAC +0.2 FS range 3	1	164	K61, U27
				"C", "DF", "C SUPP" DACs set to "0" (steps 13-15)			
13	DF	0T	0T	DF SUPP DAC +FS range 1	10	82	U10, U11, U12
14	DF	0T	0T	DF SUPP DAC +FS range 2	1	82	K62, U26
15	DF	0T	0T	DF SUPP DAC +0.2 FS range 3	1	164	K63, U26
16	C	0T	0T	All 4 DACs set to "0"	1	10	See steps 20-23 of Table 10
17	C	0T	100T	All 4 DACs set to "0"	1	61	Open circuit if error >41 bits K23,U21
17	C	0T	200T	All 4 DACs set to "0"	1	4	K24, U21
18	C	0T	300T	All 4 DACs set to "0"	1	4	K25, U21
19	C	0T	400T	All 4 DACs set to "0"	1	4	K26, U21
20	C	0T	500T	All 4 DACs set to "0"	1	4	K27, U21
	C	0T	500T	"C SUPP DAC" set to -2176 bits on range 3	1	-	K60, K61, U27
	C	0T	600T	New ref value measured in this step	1	-	K28, U21
21	C	0T	700T	"C SUPP DAC" set to -2176 bits on range 3	1	4	K29, U21
22	C	0T	800T	"C SUPP DAC" set to -2176 bits on range 3	1	4	K30, U22
23	C	0T	900T	"C SUPP DAC" set to -2176 bits on range 3	1	4	K31, U22
24	C	0T	1000T	"C SUPP DAC" set to -2176 bits on range 3	1	4	K32, U22

Table 11: Relay PCB Calibration Checks (contd)

Test No.	Meas Chan C/DF	N_x Winding (Turns)	N_s Winding (Turns)	Multiplier DAC & Range Settings	Analog U12 Gain	Error Allowed A/D Bits	Possible Defective Component
25	C	0T	0T	All 4 DACs set to "0"	10	10	See steps 20-23 of Table 10
26	C	0T	10T	All 4 DACs set to "0"	10	61	Open circuit if error >41 bits K34, U23
26	C	0T	20T	All 4 DACs set to "0"	10	10	K35, U23
27	C	0T	30T	All 4 DACs set to "0"	10	10	K36, U23
28	C	0T	40T	All 4 DACs set to "0"	10	10	K37, U23
29	C	0T	50T	All 4 DACs set to "0"	10	10	K38, U23
	C	0T	50T	"C SUPP DAC" set to -2176 bits on range 2	10	-	K60, U27
	C	0T	60T	New ref value measured in this step	10	-	K39, U23
30	C	0T	70T	"C SUPP DAC" set to -2176 bits on range 2	10	10	K40, U23
31	C	0T	80T	"C SUPP DAC" set to -2176 bits on range 2	10	10	K41, U24
32	C	0T	90T	"C SUPP DAC" set to -2176 bits on range 2	10	10	K42, U24
33	C	0T	100T	"C SUPP DAC" set to -2176 bits on range 2	10	10	K43, U24
	C	0T	1T	All 4 DACs set to"0" New ref value measured	10	-	K45, U25
34	C	0T	2T	All 4 DACs set to "0"	10	10	K46, U25
35	C	0T	3T	All 4 DACs set to "0"	10	10	K47, U25
36	C	0T	4T	All 4 DACs set to "0"	10	10	K48, U25
37	C	0T	5T	All 4 DACs set to "0"	10	10	K49, U25
38	C	0T	6T	All 4 DACs set to "0"	10	10	K50, U25
39	C	0T	7T	All 4 DACs set to "0"	10	10	K51, U25
40	C	0T	8T	All 4 DACs set to "0"	10	10	K52, U26
41	C	0T	9T	All 4 DACs set to "0"	10	10	K53, U26
42	C	0T	10T	All 4 DACs set to "0"	10	10	K54, U26
	DF	0T	0T	"C", "C SUPP", "DF SUPP" DACs set to "0" (steps 43-47)			
43	DF	0T	0T	"DF DAC" + FS range 3	1	10	K55, K56, U27
44	DF	0T	100T	"DF DAC" + FS range 3	1	61	Open circuit if error >41 bits K23, U21
44	DF	0T	200T	"DF DAC" + FS range 3	1	4	K24, U21
45	DF	0T	300T	"DF DAC" + FS range 3	1	4	K25, U21
46	DF	0T	400T	"DF DAC" + FS range 3	1	4	K26, U21
47	DF	0T	500T	"DF DAC" + FS range 3	1	4	K27, U21
	DF	0T	500T	"C & DF SUPP" DACs set to -2176 bits on range 3	1	-	K60, K61, U27
		0T	600T	New ref value measured in this step	1	-	K28, U21
48	DF	0T	700T	"C & DF SUPP" DACs set to -2176 bits on range 3	1	4	K29, U21
49	DF	0T	800T	"C & DF SUPP" DACs set to -2176 bits on range 3	1	4	K30, U22
50	DF	0T	900T	"C & DF SUPP" DACs set to -2176 bits on range 3	1	4	K31, U22
51	DF	0T	1000T	"C & DF SUPP" DACs set to -2176 bits on range 3	1	4	K32, U22

Table 11: Relay PCB Calibration Checks (contd)

Test No.	Meas Chan C/DF	N_z Winding (Turns)	N_s Winding (Turns)	Multiplier DAC & Range Settings	Analog U12 Gain	Error Allowed A/D Bits	Possible Defective Component
				"C", "C SUPP", "DF SUPP" DACs set to "0" (steps 52-56)			
52	DF	0T	0T	"DF DAC" + FS range 3	10	10	See steps 20-23 of Table 10 K55, K56, U27
53	DF	0T	10T	"DF DAC" + FS range 3	10	61	Open circuit if error >41 bits K34, U23
53	DF	0T	20T	"DF DAC" + FS range 3	10	10	K35, U23
54	DF	0T	30T	"DF DAC" + FS range 3	10	10	K36, U23
55	DF	0T	40T	"DF DAC" + FS range 3	10	10	K37, U23
56	DF	0T	50T	"DF DAC" + FS range 3	10	10	K38, U23
	DF	0T	50T	"C SUPP"&"DF SUPP" DACs set to -2176 bits on range 2 (steps 57-60)	10	-	K60, K62, U26, U27
	DF	0T	60T	New ref value measured in this step	10	-	K39, U23
57	DF	0T	70T		10	10	K40, U23
58	DF	0T	80T		10	10	K41, U24
59	DF	0T	90T		10	10	K42, U24
60	DF	0T	100T		10	10	K43, U24
	DF	0T	0T	Set "C", "C SUPP", "DF SUPP" DACs to "0" (steps 61-69)			See steps 20-23 of Table 10
	DF	0T	1T	"DF DAC" + FS range 3 Ref value measured	10	-	K55, K56, U27
61	DF	0T	2T	"DF DAC" + FS range 3	10	10	K46, U25
62	DF	0T	3T	"DF DAC" + FS range 3	10	10	K47, U25
63	DF	0T	4T	"DF DAC" + FS range 3	10	10	K48, U25
64	DF	0T	5T	"DF DAC" + FS range 3	10	10	K49, U25
65	DF	0T	6T	"DF DAC" + FS range 3	10	10	K50, U25
66	DF	0T	7T	"DF DAC" + FS range 3	10	10	K51, U25
67	DF	0T	8T	"DF DAC" + FS range 3	10	10	K52, U25
68	DF	0T	9T	"DF DAC" + FS range 3	10	10	K53, U26
69	DF	0T	10T	"DF DAC" + FS range 3	10	10	K54, U26
	DF	0T	0T	"C", "C SUPP", "DF SUPP" DACs set to "0" (steps 70-73)			See steps 20-23 of Table 10
70	DF	0T	0T	"DF DAC" + FS range 3	10	10	K55, K56, U27
71	DF	0T	50T	"DF DAC" + FS range 3	10	102	K55, K56, U27
72	DF	0T	50T	"DF DAC" + 0.1 FS range 4	10	102	K55, K56, K57, U27
73	DF	0T	50T	"DF DAC" + FS range 2	10	41	K55, U27

Table 12: Function of Relays and CMOS Switches

Relay	Function	Relay	Function
K1	Power breaker	K44	Ns 1 turn 0
K2	Line relay	K45	" 1
K3	HV OFF relay	K46	" 2
K4	HV OUTPUT relay	K47	" 3
K5	Reverse polarity	K48	" 4
K6	Open ground	K49	" 5
K7	Over V & I relay	K50	" 6
K8	Testing lamp relay	K51	" 7
K9	Nx 0	K52	" 8
K10	Nx 1T	K53	" 9
K11	Nx 10T	K54	" 10
K12	Nx 100T		
		K55	% DF range 2
K13	CxL red 1	K56	% DF range 3
K14	CxL red 2	K57	% DF range 4
K15	CxL blue 1	K58	C fine balance range 2
K16	CxL blue 2	K59	C fine balance range 3
K17	GST	K60	C supp range 2
K18	UST	K61	C supp range 3
K19	Nx calib	K62	DF supp range 2
K20	Cs short	K63	DF supp range 3
K21	Ns calib	K64	Triac control
		K65	Short triac
K22	Ns 100 turn 0		
K23	" 1	CMOS	
K24	" 2	U33	Measure/calibrate
K25	" 3	U26	Gain 1 (always) A1 logic lo A2, A3, A4 logic hi
K26	" 4		
K27	" 5	U20	Gain 1, 10, 100 1000
K28	" 6	U3	Multiplexer "0" V initial
K29	" 7	U60	Line ref V/ Test ref V
K30	" 8	U44	Measurement/DAC cal
K31	" 9	U51	Measurement/DAC cal
K32	" 10		
K33	Ns 10 turn 0		
K34	" 1		
K35	" 2		
K36	" 3		
K37	" 4		
K38	" 5		
K39	" 6		
K40	" 7		
K41	" 8		
K42	" 9		
K43	" 10		

REPAIR

AVO International offers a complete repair service and recommends that its customers take advantage of this service in the event of any equipment malfunction. Please indicate all pertinent information including problem, symptoms, and attempted repairs. Equipment returned for repair must be shipped prepaid and insured and marked for the attention of the Repair Department.

GLOSSARY

Use only in accordance with Instruction Manual.

High-voltage warning

arc-over — A disruptive discharge in the form of an arc or spark between two electrical conductors or between a conductor and earth (also sparkover or flashover).

bridge symbols — Bridge symbols used in Tables 3, 4, 5, 7, 8, and 9 are defined as follows: R = red, B = blue, and G = green.

CAP — Capacitance

dissipation factor (DF) — The ratio of energy dissipated to the energy stored in an element for one cycle.

GST — Grounded specimen test

GSTg — Grounded specimen test using guard connection

hot collar — A conductive band used to test for dielectric losses in bushings.

LCD — Liquid crystal display

LED — Light-emitting diode

nomograph — A graphic representation consisting of several lines marked off to scale and arranged so that by using a straightedge to connect known values on two lines, an unknown value can be read at the intersection with another line.

permittivity — The ability of a dielectric to store electrical potential energy under the influence of an electric field.

pothead — A device that seals the end of a cable and provides insulated egress for the conductor or conductors.

power factor — (PF) the ratio of total watts to the total rms volt-amperes.

safety ground stick	An insulated stick (sometimes called a hot stick) with a hook type electrode connected to ground via an insulated cable. In some designs, frequently known as high voltage discharge sticks, a resistor is connected between the electrode and the ground cable. Both are used to discharge capacitive specimens by providing a low impedance path to ground. They must be suitably rated for the voltage and capacitance of the specimen to be discharged.
UST	Ungrounded specimen test

WARRANTY

Products supplied by AVO International are warranted against defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair must be shipped prepaid and insured. This warranty does not include batteries, lamps, or other similar items, where the original manufacturer's warranty shall apply. We make no other warranty. The warranty is void in the event of abuse (failure to follow recommended operating procedures) or failure by the customer to perform specific maintenance as indicated in this manual.

APPENDIX A

BAR CODE GENERATOR PROGRAM

BAR CODE GENERATOR PROGRAM

Purpose:

The bar code generator program is used to create bar code identification labels for the C&DF Test Set. The program generates bar codes in the Code39 format.

Installation:

The bar code generator program is contained in a single file (BARCODE.EXE) on the original shipping diskette. It should be copied to a work diskette or to a hard drive. The additional files on the diskette are for the data key and could all be combined in one subdirectory.

Usage:

To print bar codes requires an IBM PC graphics compatible printer, i.e., a printer that can handle IBM PC graphics. Connect the printer to the LPT1 parallel port.

To operate the bar code generator, log to the disk drive that contains the program or have the directory in your path statement. The following is the format to run the program.

BARCODE CODE NAME (optional Left Margin)

Where:

CODE = The text to be bar coded.
NAME = The name to be printed under the bar code.
Left Margin = Number of spaces, between 0 and 70, to print before the code. Default is 5.

The valid characters that can be used in a bar code are the numbers, 0 to 9; the letters, A to Z; and several special codes: '+', '-', '.', and '/'. The letters can be entered in capital or small characters, the program will convert to all caps. The space character cannot be used as part of the code or in the name. Instead, use any of the special codes in the code and the dash or an underscore in the name to separate words.

The Left Margin entry is optional and can be used to control the position of the bar code on the page horizontally. The valid numbers are 0 through 70. The system defaults to a value of 5. Any number outside the range will use the default.

Help is available on the screen by typing BARCODE and pressing ENTER. The above Where: definitions will be displayed for your assistance.

APPENDIX B

DATA-KEY DATA DOWNLOADER PROGRAM

Data-Key Data DownLoader Program

Purpose:

This program is used in conjunction with the DataKey PKS232 Interface Module. It communicates with the module to retrieve the test results from a data key.

Installation:

Connect the PKS232 Interface Module to a power source using the power converter plug, and then connect the RS232 cable between the module and a Comm port on your PC. Turn on the power switch on the back of the module and insert a data key.

The Data-Key DownLoader files are contained on the original shipping diskette. To install the program, copy all the files to a work diskette or to your hard drive. Creating a working directory on your hard drive keeps the files created by the Data-Key DownLoader separate from other programs and keeps your hard drive more organized.

Usage:

To operate the Data-Key DownLoader, log to the disk drive and or directory that contains the program and type the file name "DKEY" followed by ENTER.

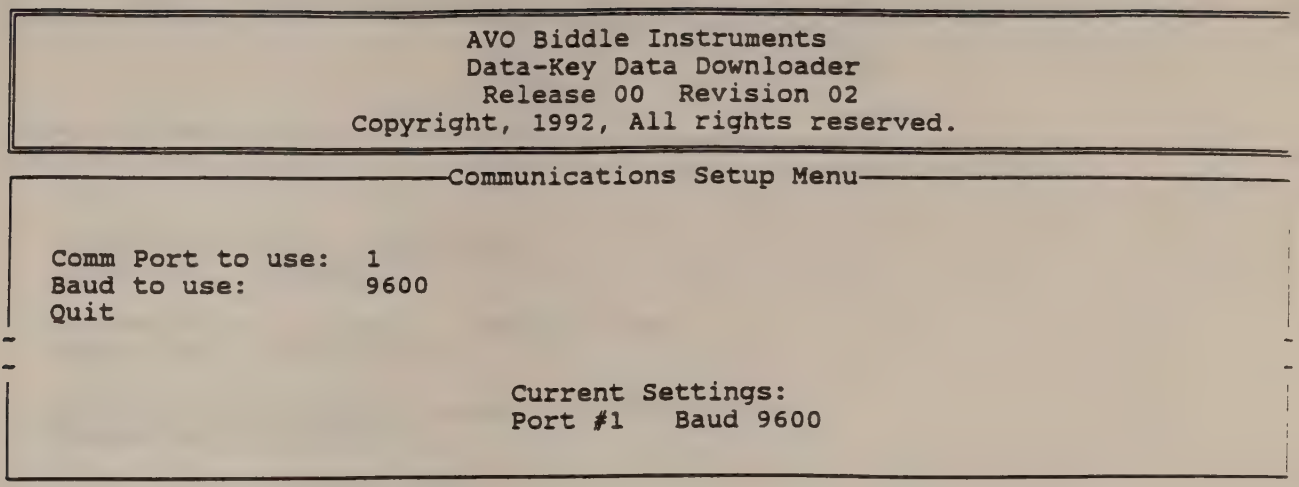
The DKEY program starts with a "splash" screen that presents the company logo, identifies the program and its release and revision. Next a magenta screen appears to allow you to review the preset information. If the program has just been installed or there is no configuration file present, the program prompts the operator for the communications parameters and default file names.

How to move around:

To move around the menus, use the cursor keys. The escape key exits a menu screen. Pressing ENTER at any highlighted menu item causes the screen for that item to appear. If the cursor is in a data field, pressing ENTER causes the currently shown value to be accepted.

First time operation:

If this is the first time you have run the program, the following screen will be presented:



To use the software requires this information. If you fail to set this information up correctly, the software will not work correctly when you attempt to download information from the DataKey Interface Module. The data screen fields are described as follows:

Comm Port to use:
The first item in this menu will be highlighted. If the default communications port is the one you want to use, press ENTER. You are allowed to use either comm 1 or 2. Currently comms 3 and 4 are not supported.

Baud to use:
The baud setting to use is determined by the selection on the interface module. The interface module is factory-set to 9600 BAUD, so verify that this is the value set. No error checking is performed by the downloader software so an incorrect value will cause problems.

Quit:
When you have made all the changes, move the cursor to quit and press ENTER.

On a first time power up, the program will present a second screen:

```
                    AVO Biddle Instruments
                    Data-Key Data Downloader
                    Release 00  Revision 02
          Copyright, 1992, All rights reserved.

                    File Name Selection Menu

  Downloaded File:  DATAKEY.DAT
  Change To:  DATAKEY.DAT

  Process File (all data):  DKEYASCI.TXT
  Change To:  DKEYASCI.TXT

  Process File (selected records): DKEYPICK.PRN
  Change To: DKEYPICK.PRN

  Error File:  KEYERROR.TXT
  Change To:  KEYERROR.TXT

  Quit
```

Downloaded File: DATAKEY.DAT
Change To: DATAKEY.DAT

This prompt is offering a default name for a file that will hold the raw data from the C&DF data key. This is the file that will hold the data from the main menu selection of "Save Raw Data to File." This data will be just as it is stored on the data key. You can change this file name and include a path. The field is 40 characters long, so your file specification and path must fit in that space.

Process File (all data): DKEYASCI.TXT
Change To: DKEYASCI.TXT

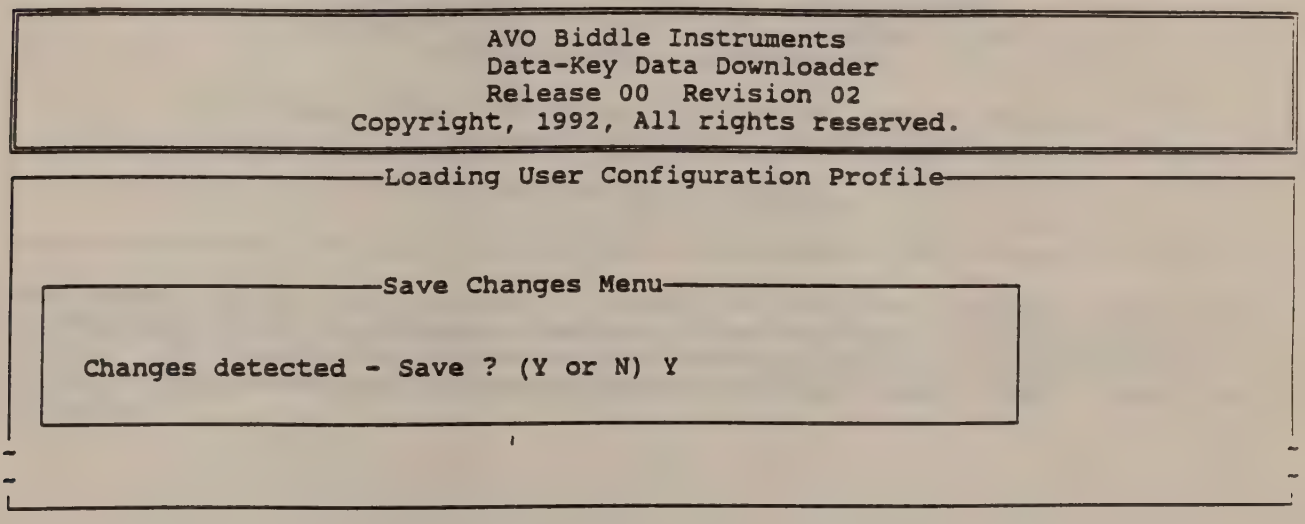
This prompt offers a default name for a file to hold the processed data from the C&DF data key. This is the file that holds the data from the main menu selection of "Convert All Records." These data are formatted to be retrieved into LOTUS 1-2-3, QUATTRO, PARADOX, or perhaps another data-base program. The output is comma delimited and text is quoted. Dates are considered text. A record is terminated by a carriage return character. You may change this file name and you may include a path. The field is 40 characters long, so your file specification and path must fit in that space.

Process File (selected records): DKEYPICK.PRN
Change To: DKEYPICK.PRN
This prompt offers a default name for a file to hold the processed data frc the C&DF data key. This is the file that holds the data from the Browse Dat menu selection of "Store." These data are formatted the same as that in th all data selection above.

Error File: KEYERROR.TXT
Change To: KEYERROR.TXT
This file is used to report errors that occurred during program execution. Sometimes errors may disappear before the user sees them or the program ma be running unattended. By viewing this file, the operator can review the session to see if any problems were encountered.

Quit
This field is used to end data entry and continue with the program.

Because this was a first time start up, the program now asks the operator if it is alright to save the configuration information just entered. If it is, press ENTER, otherwise press "N" and then press ENTER. The screen appears as follows:

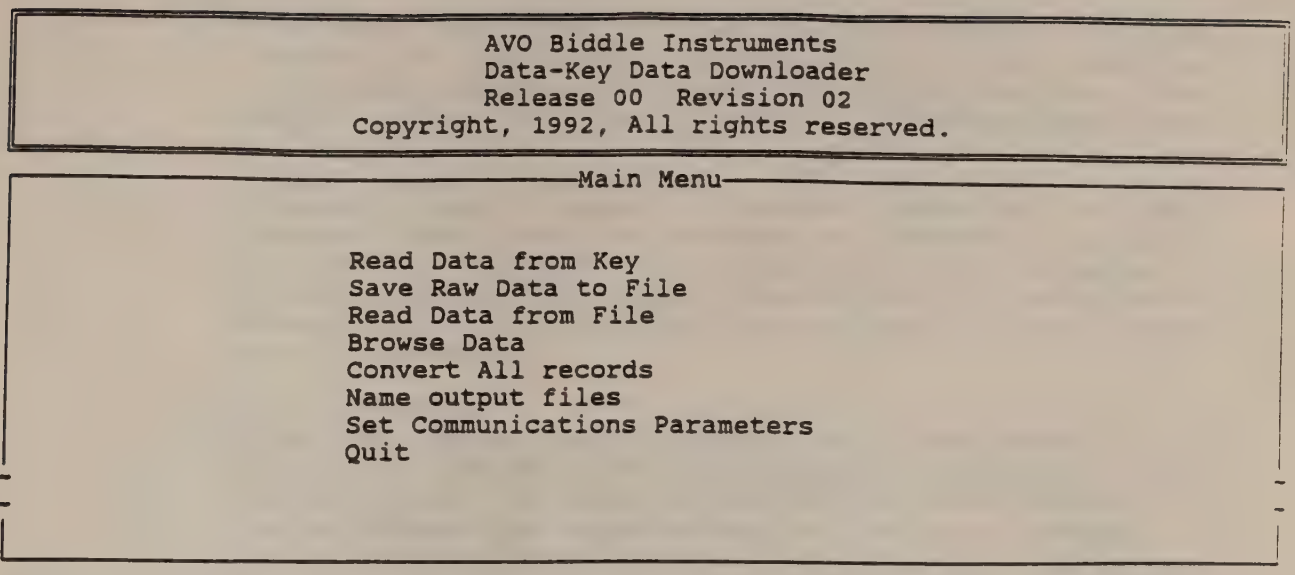

AVO Biddle Instruments
Data-Key Data Downloader
Release 00 Revision 02
Copyright, 1992, All rights reserved.
Loading User Configuration Profile
Save Changes Menu
Changes detected - Save ? (Y or N) Y

Normal Operation:

Once the program has been set up with the configuration information, its first sign-on screen will look like this.

```
                    AVO Biddle Instruments
                    Data-Key Data Downloader
                    Release 00  Revision 02
              Copyright, 1992, All rights reserved.

          ----------Loading User Configuration Profile----------


                          Comport = 1
                          Baud = 9600


                          Data Files for:
              Downloaded Data (raw data): DATAKEY.DAT
            Converted Data (all records): DKEYASCI.TXT
          Converted Data (select records): DKEYPICK.TXT
                    Error Log Data: KEYERROR.TXT

          To make changes to the settings above, please use one
                    of the menu options on the Main Menu

                          Press any key to continue
```

This screen gives the operator a chance to view the current configuratio information before the main menu comes up. The main menu will appear in about 3 seconds. If the operator wishes to get there quicker, any displayable key wil interrupt this screen and move the program to the main menu. This is shown in the following:



The Main Menu:

Read Data from Key
This menu selection communicates with the DataKey PKS232 Interface Module. This unit must be connected to the communication port selected by the user during the configuration setup. Selecting this option reads all data from the key into the memory on the PC.

Save Raw Data to File
This menu selection saves the data read by "Read Data from Key" to a raw data file. This file is not formatted and contains the binary data just as it was read from the key. It cannot be used by other programs.

Its purpose is to allow the contents of a data key to be dumped to the hard or floppy disk of the PC and quickly return the key to service. At a later time the option "Read Data from File" may be used to retrieve the data for viewing and saving to an ASCII file. This raw data file is overwritten each time this option is selected. The user has the option to type in a new file name before saving the data.

Read Data from File
This menu selection is used to retrieve the data saved by "Save Raw Data to File."

Browse Data

This menu selection is used to view the data records stored from the key. During a browse the user may increment forward or backward through the records. Each record may be individually printed. And each record may be appended to a file that is specified in the "Name output files" menu option. If this file is to be cleared, simply erase it before entering the DKEY program. When print is selected the operator is asked if a header is required. If the default "Y" is accepted by pressing ENTER, the header information will be printed, otherwise it will not and the currently viewed record will be printed.

Convert All records

This menu selection produces a file that contains all valid data records from the currently loaded key data. The file format is comma delimited quoted ASCII text. It can be viewed with editors and the DOS type command. It loads into data-base packages and spreadsheet programs. This option overwrites the current file by the same name; however, the operator is prompted for a filename change before actually saving the file.

Set Communications Parameters

This menu selection allows the operator to change the communications settings that were established the first time the program was started. The screen is the first one described in this document.

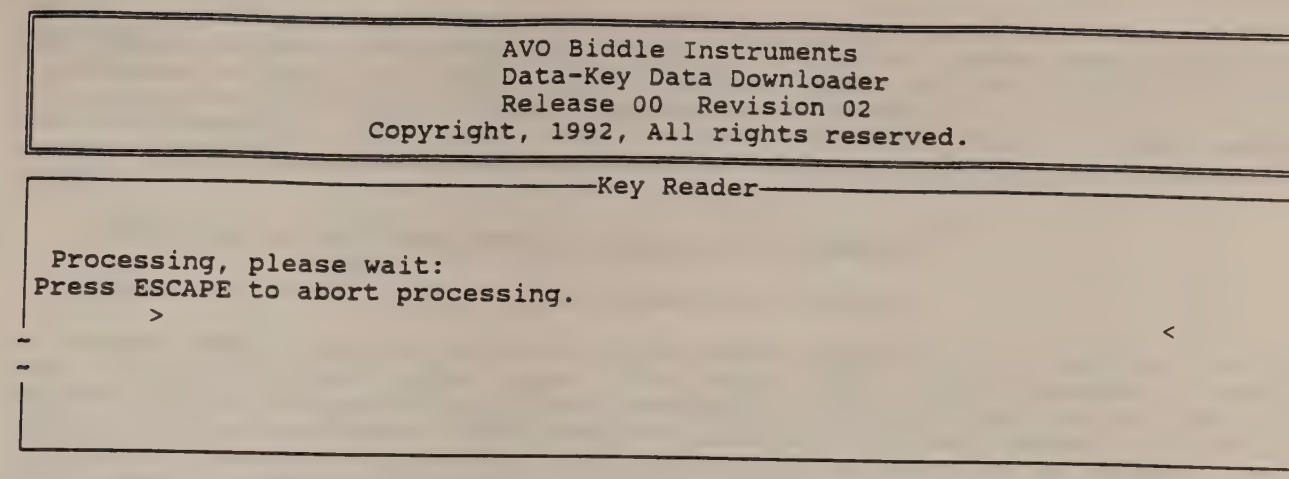
Name output files

This menu selection allows the operator to change the file names originally selected. This is the second screen described.

Quit

This selection terminates the program. All files will be closed. The communications port will be closed and the interrupt handler shut down. If any changes were made to the configuration items via the menu selections, the operator will be asked to save the changes as previously described in the third screen. To use the software in a different configuration one time only, say no to the save question otherwise the changes made during the current session will be saved.

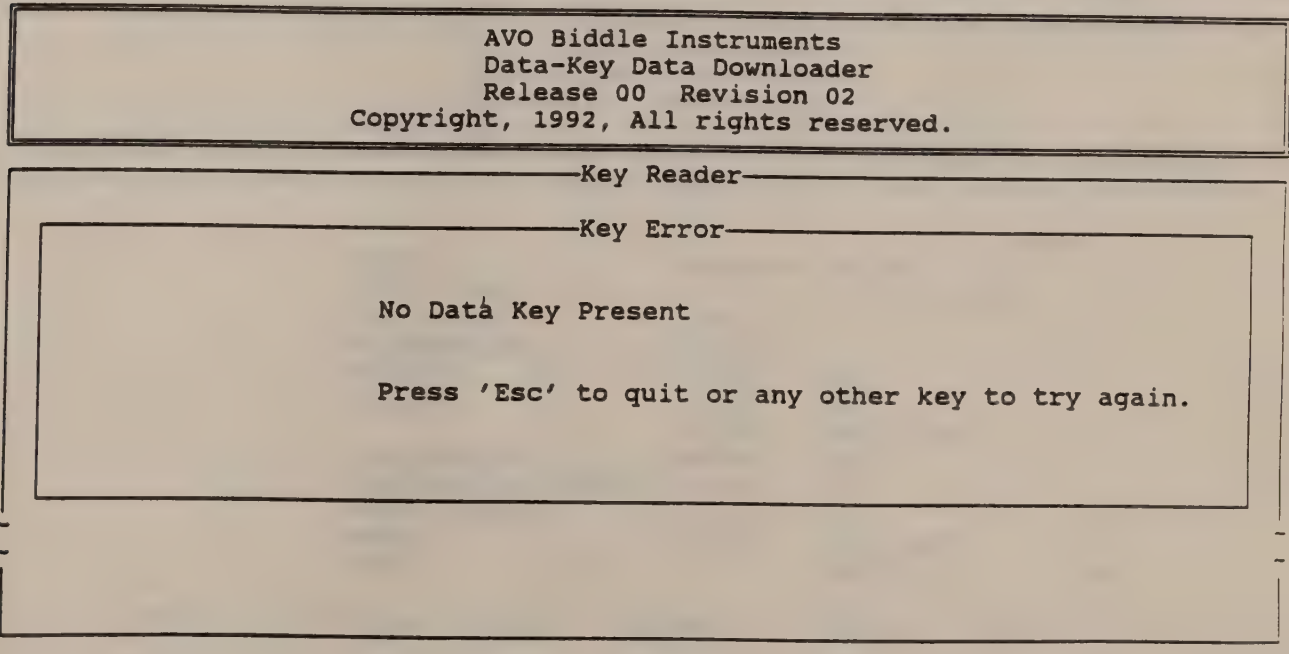
The "Read Data from Key" selection shows the following screen:



A bar moves across the screen as the data from the key is read into memory. Upo successfully reading the key, the following message is displayed below the bar:

Comm port Closed!
Data successfully captured!

The system then returns to the main menu. If there is no data key inserted in th receptacle, an error message window appears on the Key Reader screen as show below.


AVO Biddle Instruments
Data-Key Data Downloader
Release 00 Revision 02
Copyright, 1992, All rights reserved.
Key Reader
Key Error
No Data Key Present
Press 'Esc' to quit or any other key to try again.

Insert a data key and press any key to continue or abort with the Escape key. Whe the system returns to the main menu, it first checks for a header record which ha been stored as the first record on the data key. There are two checks made: firs if the data key is from AVO Biddle Instruments and second if it is initialized fc the C&DF Test Set. If these tests are not satisfied, then an error messag appears in an error window similar to the preceding window. The message could b either:

"This key is not from Biddle Instruments or empty."
or
"This key is not from a C & DF catalog no. 672000."

In either case, there is no valid data to work with and any selection from th menu to view or save data shows a "No Valid Data" error message. Upon successful read with valid data, the operator can select to view the data (browse or store the data (save). The Save Raw Data to File and Convert All record selections display a window with the filename that was selected in the setup menu. This gives the operator a chance to change the default name if so desired. If the name is satisfactory, press ENTER to store the data.

The Browse Data menu selection brings up a Data View window. The data from the first legal record on the key is displayed. This is always Test ID No. 1. The data are presented in the same format as the print command on the C & DF Test Set. A menu selection appears across the bottom of the window as shown in the following:

```
                    AVO Biddle Instruments
                   Data-Key Data Downloader
                   Release 00  Revision 02
               Copyright, 1992, All rights reserved.

                          Data View

                                                        Record:    0
          DATE:. . . . . . . . 04/14/92 15:05
          TEST ID NO.: . . . . 1        CB-123-SS-ABC
          TEST MODE: . . . . . GST 4
          MEASUREMENT: . . . . C & DF
          VOLTAGE: . . . . . . 0.53     KV
          CURRENT: . . . . . . 1.016    MA
                   . . . . . . 19.35    MA @ 10KV
          CAPACITANCE: . . . . 4899.8   PF
          DISSIPATION FACTOR:. 3.16     %
          POWER FACTOR:. . . . 3.16     %
          WATTS: . . . . . . . 5.837    W @ 10KV
          CSUP =         A 0            DFSUP =         A-0

     Next      Previous  Print   FormFeed      Save      Done
```

The Next and Previous selections from the menu allow the operator to scroll through the tests from first to last. The display will not wrap from last to first or first to last.

The Print selection allows the presently displayed test to be printed. The operator will be prompted if he would like a header printed first. Select No if it is not wanted or press ENTER if it is. Again, the header and the printout will be the same as from the C & DF Test Set.

The FormFeed selection sends a form feed character to the printer to start a new page.

The Save selection saves individual data records in the file specified in the setup menu. The records are appended to the file as each is saved.

The Done selection exits the Data View window and returns to the Main Menu window.

General

As with most programs that use the comm ports, display, keyboard, and files, TSR software may cause problems. If the program does not function properly, try removing some terminate and stay resident software.

To load this data into other packages, use their import feature. The output file has been tested on Quattro.

APPENDIX C

NOMOGRAPHS

NOMOGRAPHS

% DISSIPATION FACTOR vs WATTS LOSS

The % dissipation factor can be converted rapidly to watts loss by using the appropriate nomograph (Fig. 1 to 12). When the value of capacitance and % dissipation factor is known, draw a straight line through these two known values. The watts loss is found where this line intersects the watts loss scale.

The nomographs and the ranges covered are as follows:

Figure No.	Capacitance Range (pF)	%DF Range	Doble Equivalent Test Voltage	Test Frequency (Hz)
1	10 to 1000	0.1 to 10	2.5	60
2	10 to 1000	1 to 100	2.5	60
3	100 to 10,000	0.1 to 10	2.5	60
4	10 to 1000	0.1 to 10	10	60
5	10 to 1000	1 to 100	10	60
6	100 to 10,000	0.1 to 10	10	60
7	10 to 1000	0.1 to 10	2.5	50
8	10 to 1000	1 to 100	2.5	50
9	100 to 10,000	0.1 to 10	2.5	50
10	10 to 1000	0.1 to 10	10	50
11	10 to 1000	1 to 100	10	50
12	100 to 10,000	0.1 to 10	10	50

Example (Fig. 1):

Capacitance measurement = 370 pF

Dissipation factor measurement = 1.60%

The unknown watts loss = 14.0 mW

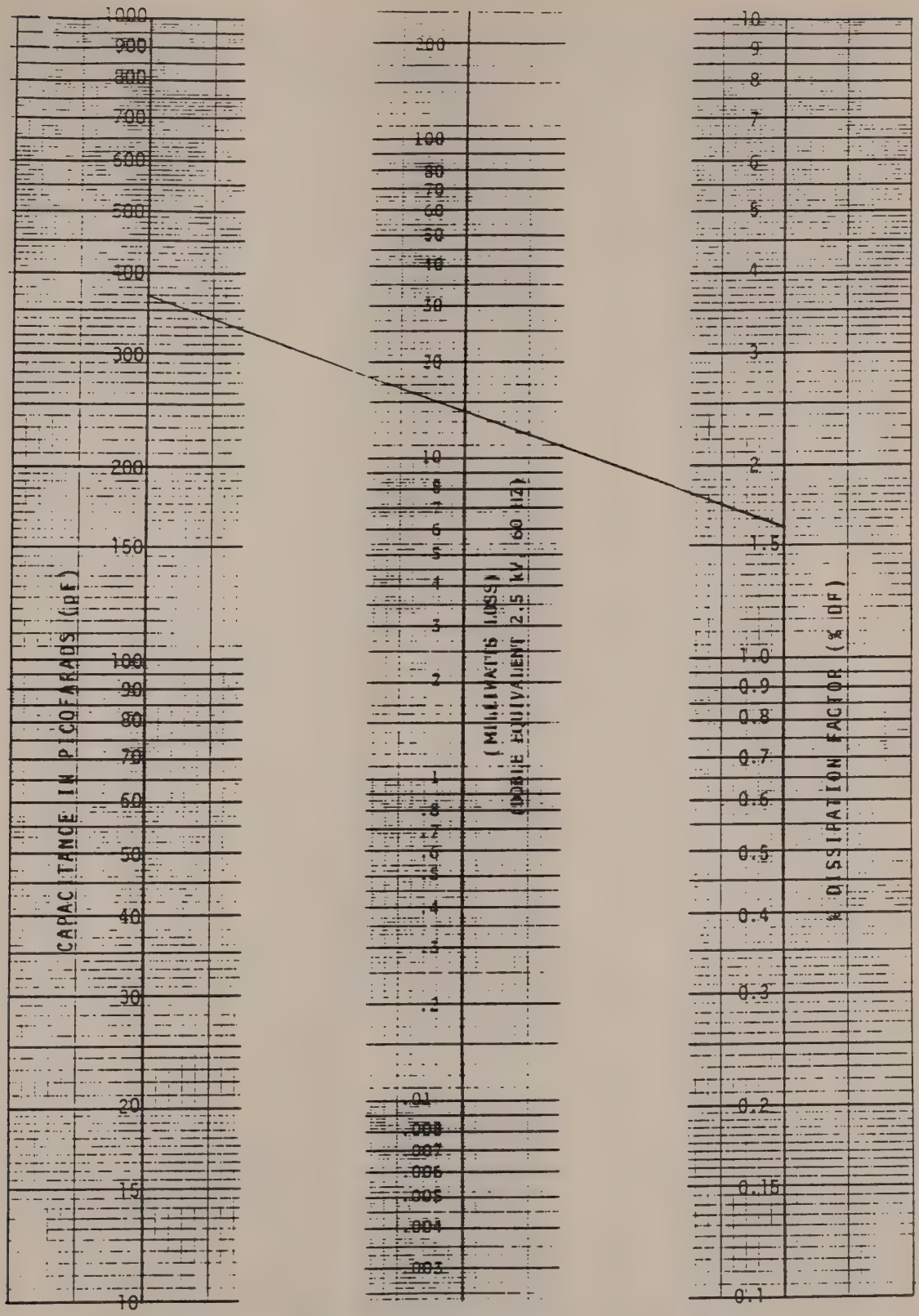


Figure 1: %DF vs. Milliwatts Loss (2.5 kV, 60 Hz)

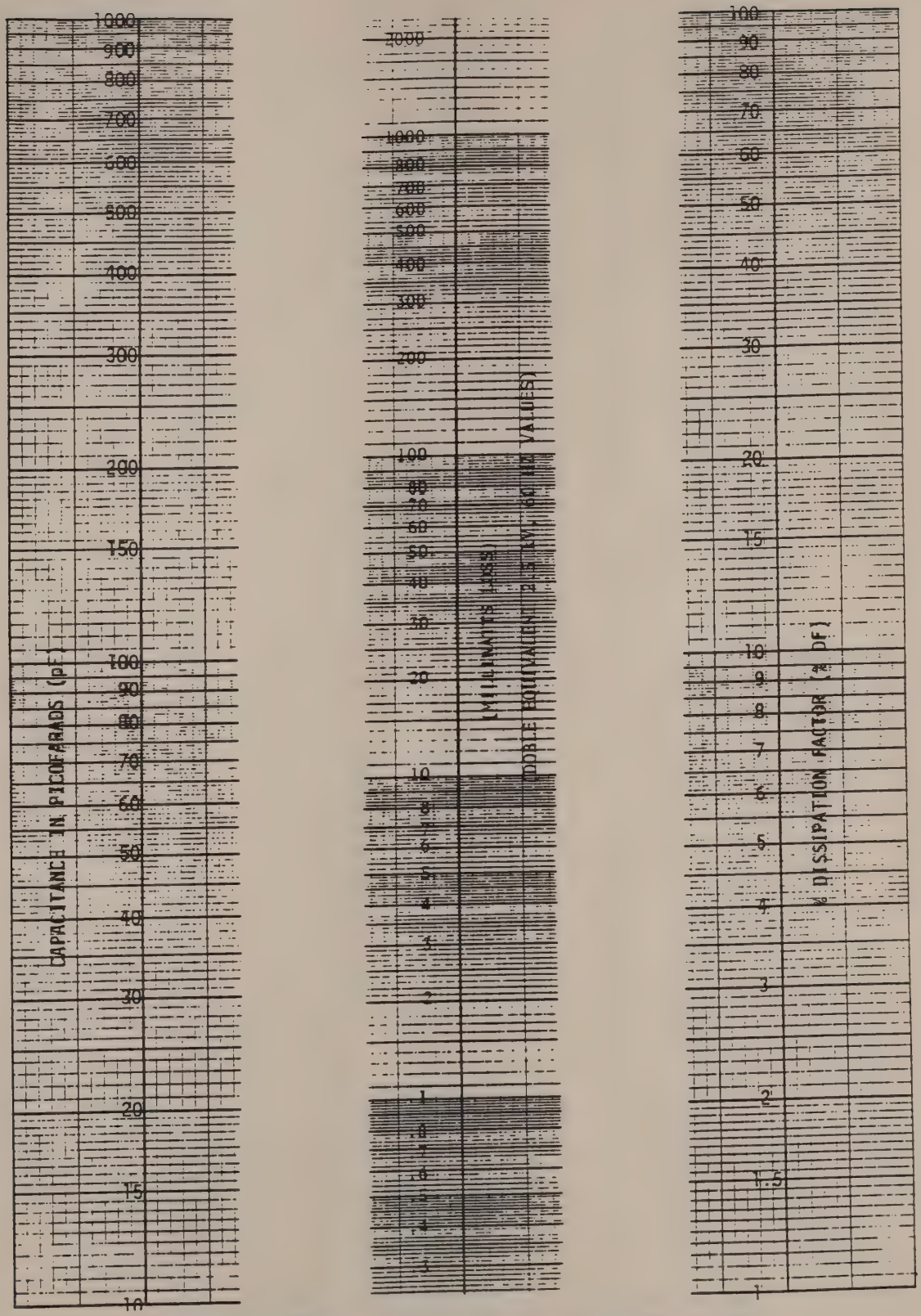


Figure 2: %DF vs. Milliwatts Loss (2.5 kV, 60 Hz)

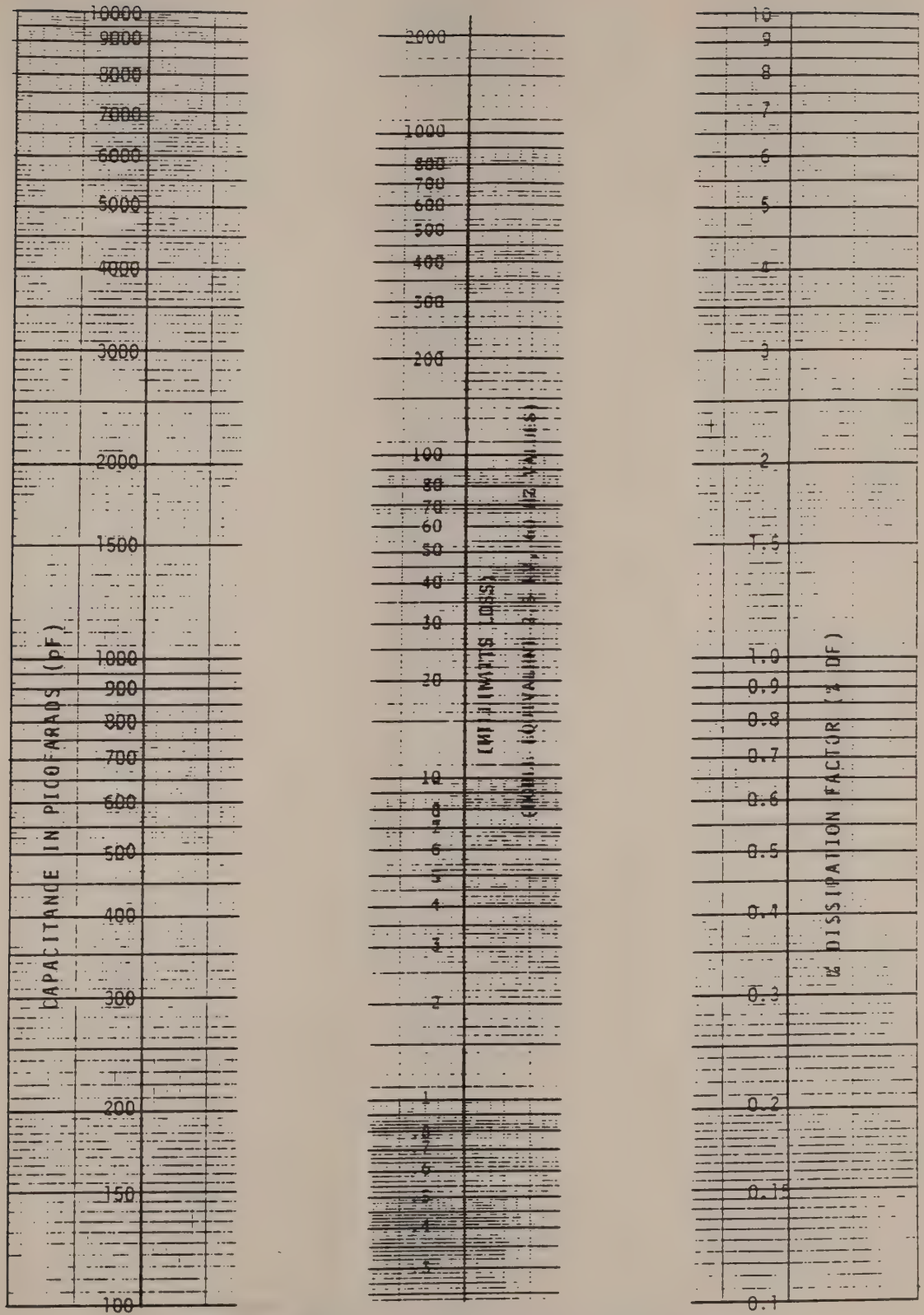


Figure 3: %DF vs. Milliwatts Loss (2.5 kV, 60 Hz)

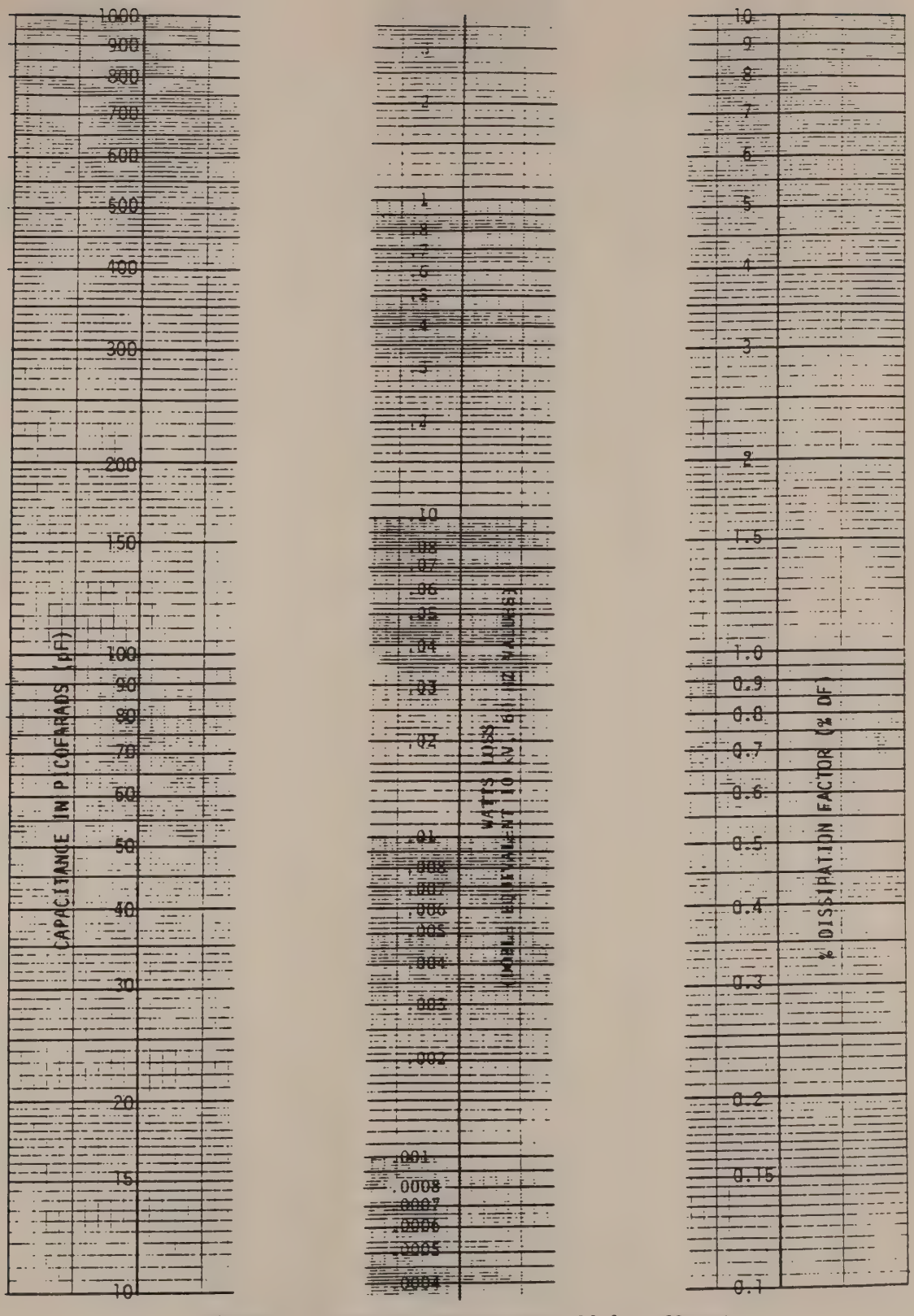


Figure 4: %DF vs. Watts Loss (10 kV, 60 Hz)

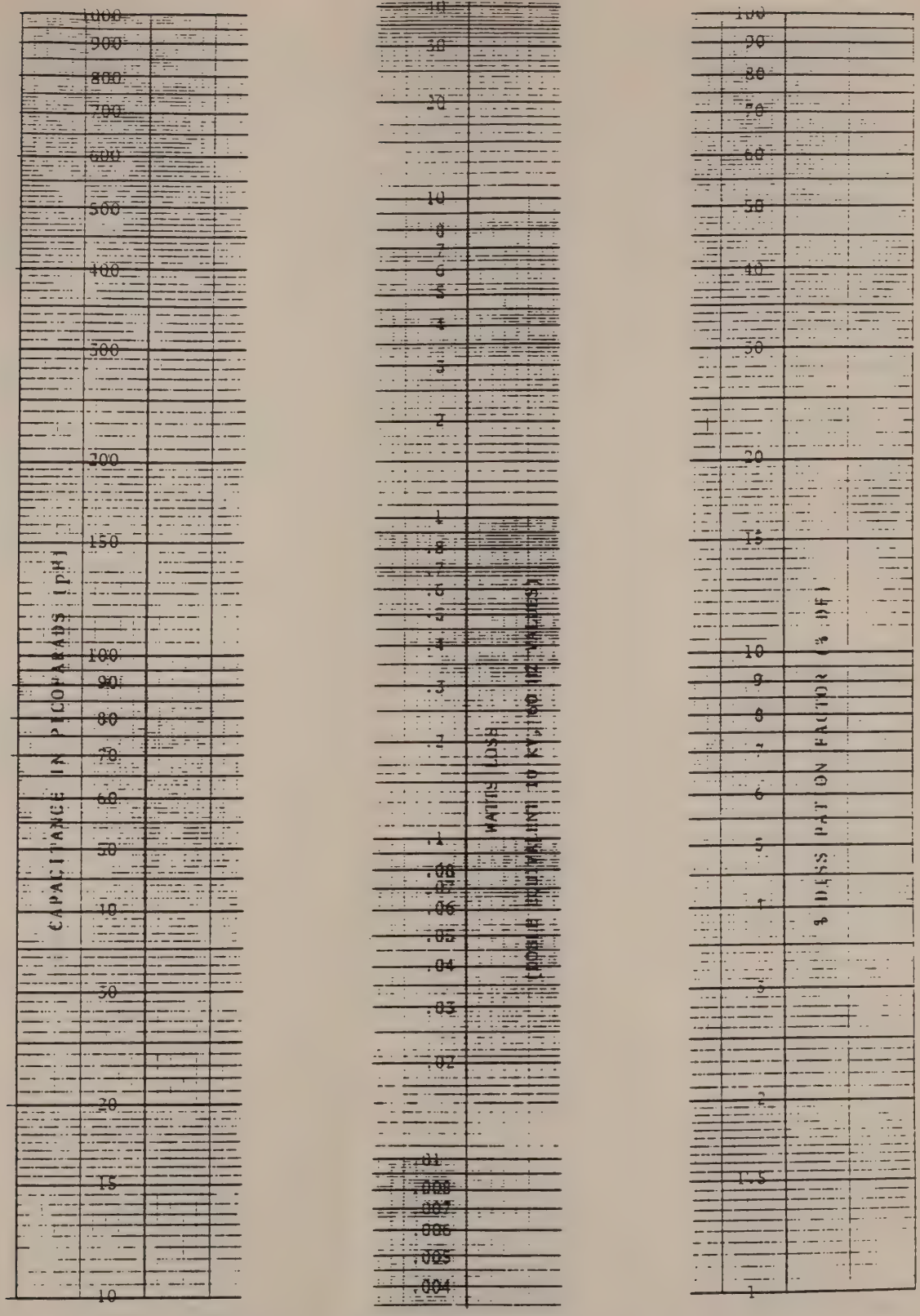


Figure 5: %DF vs. Watts Loss (10 kV, 60 Hz)

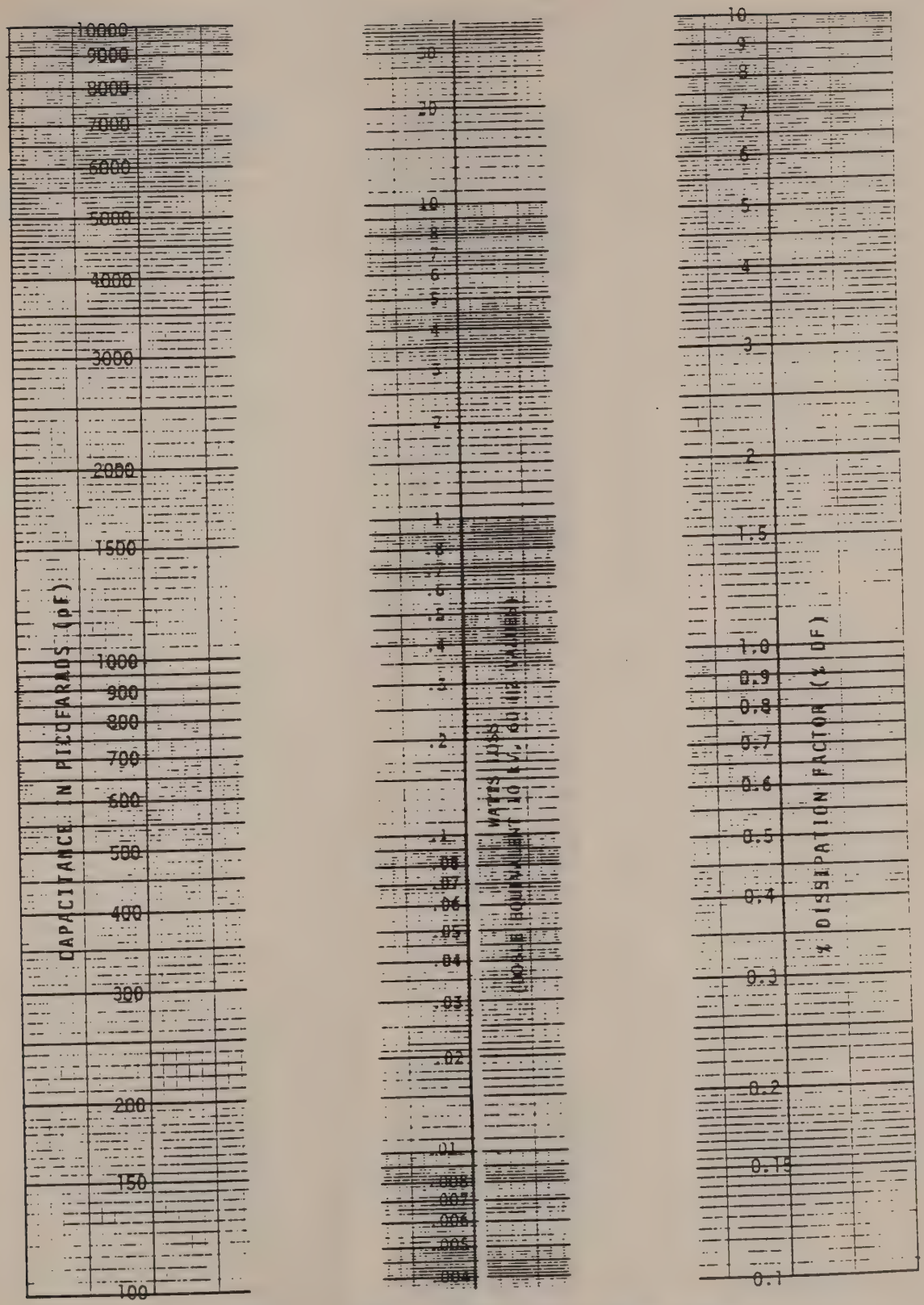


Figure 6: %DF vs. Watts Loss (10 kV, 60 Hz)

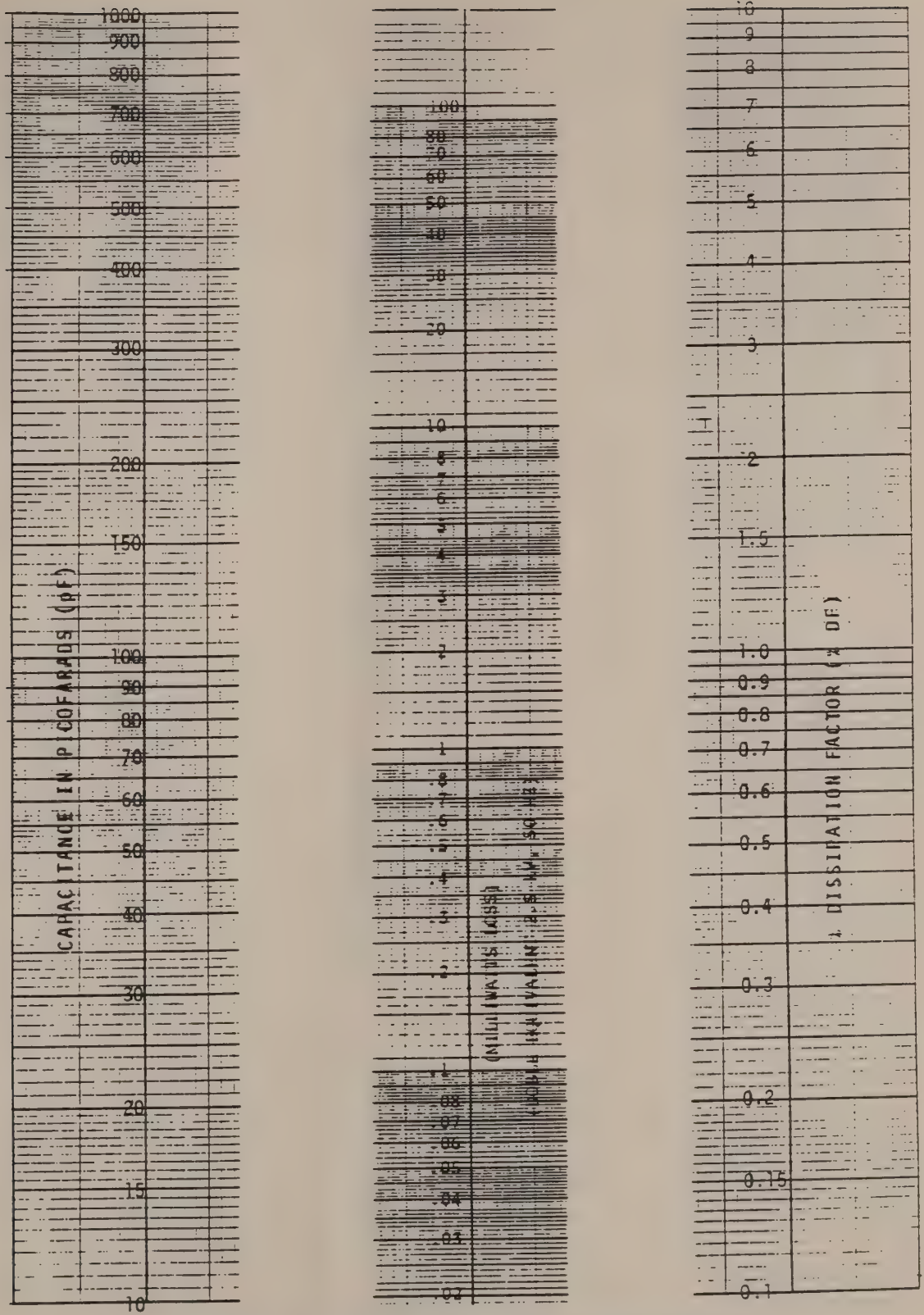


Figure 7: %DF vs. Watts Loss (10 kV, 60 Hz)

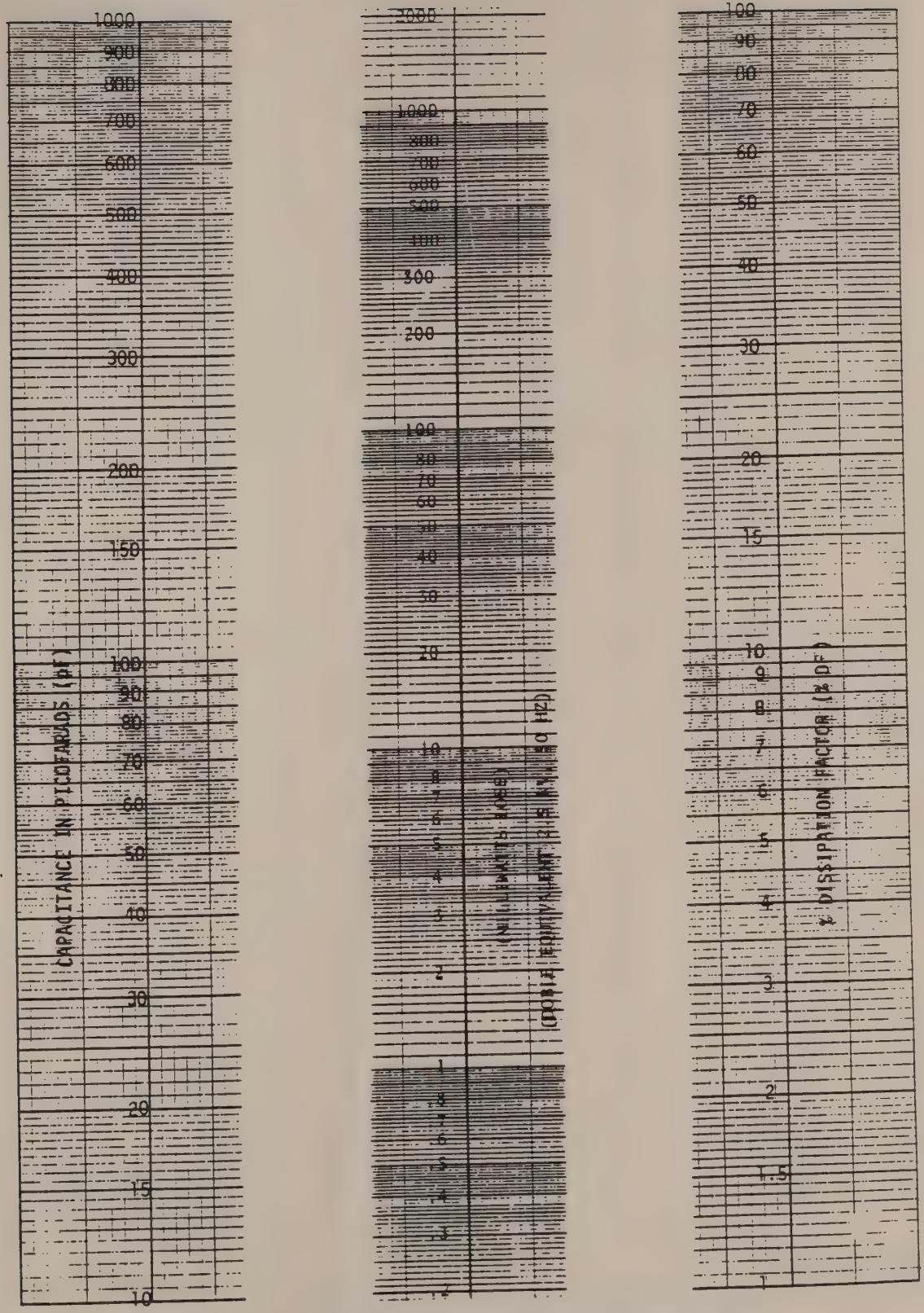


Figure 8: %DF vs. Milliwatts Loss (2.5 kV, 50 Hz)

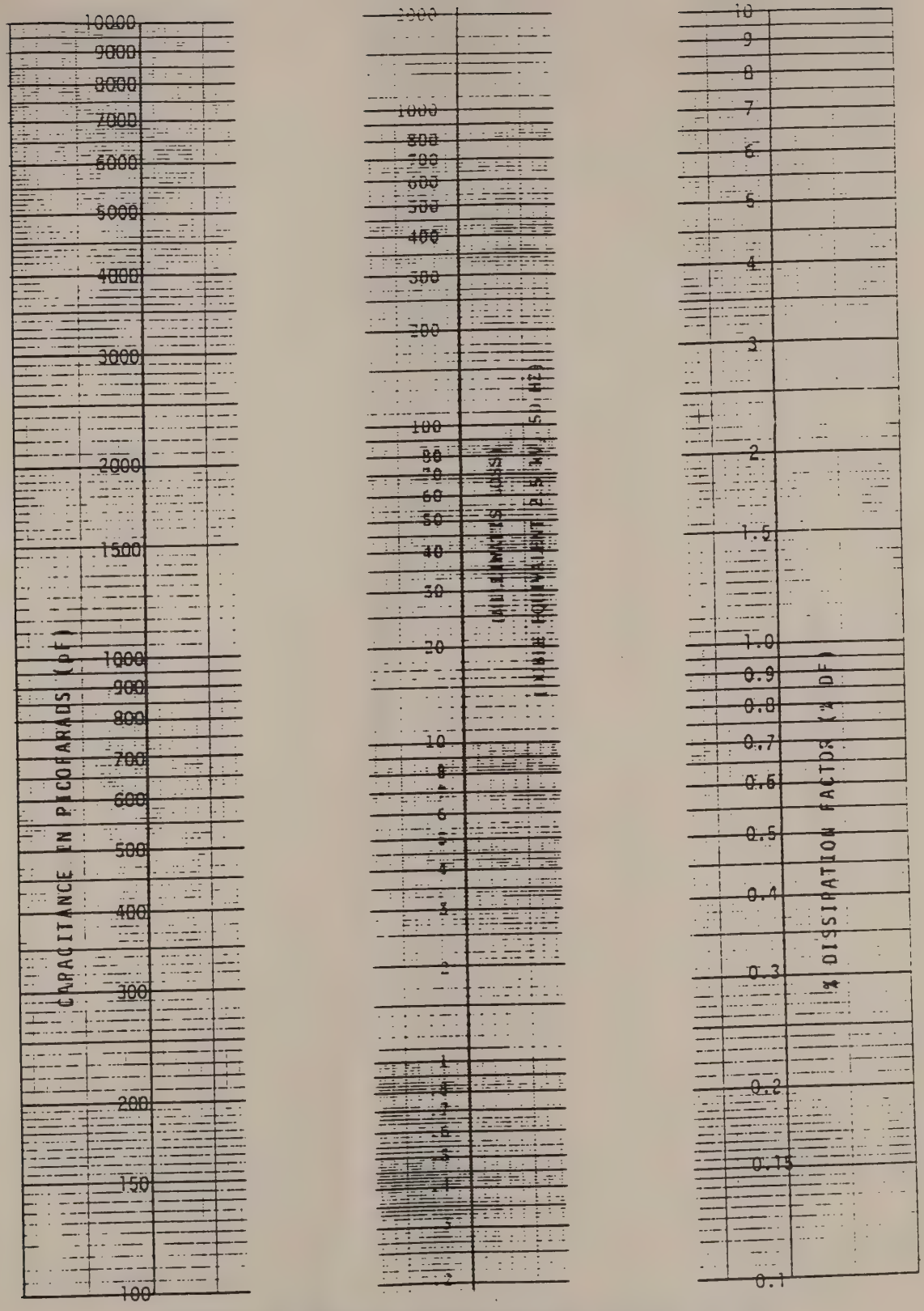


Figure 9: %DF vs. Milliwatts Loss (2.5 kV, 50 Hz)

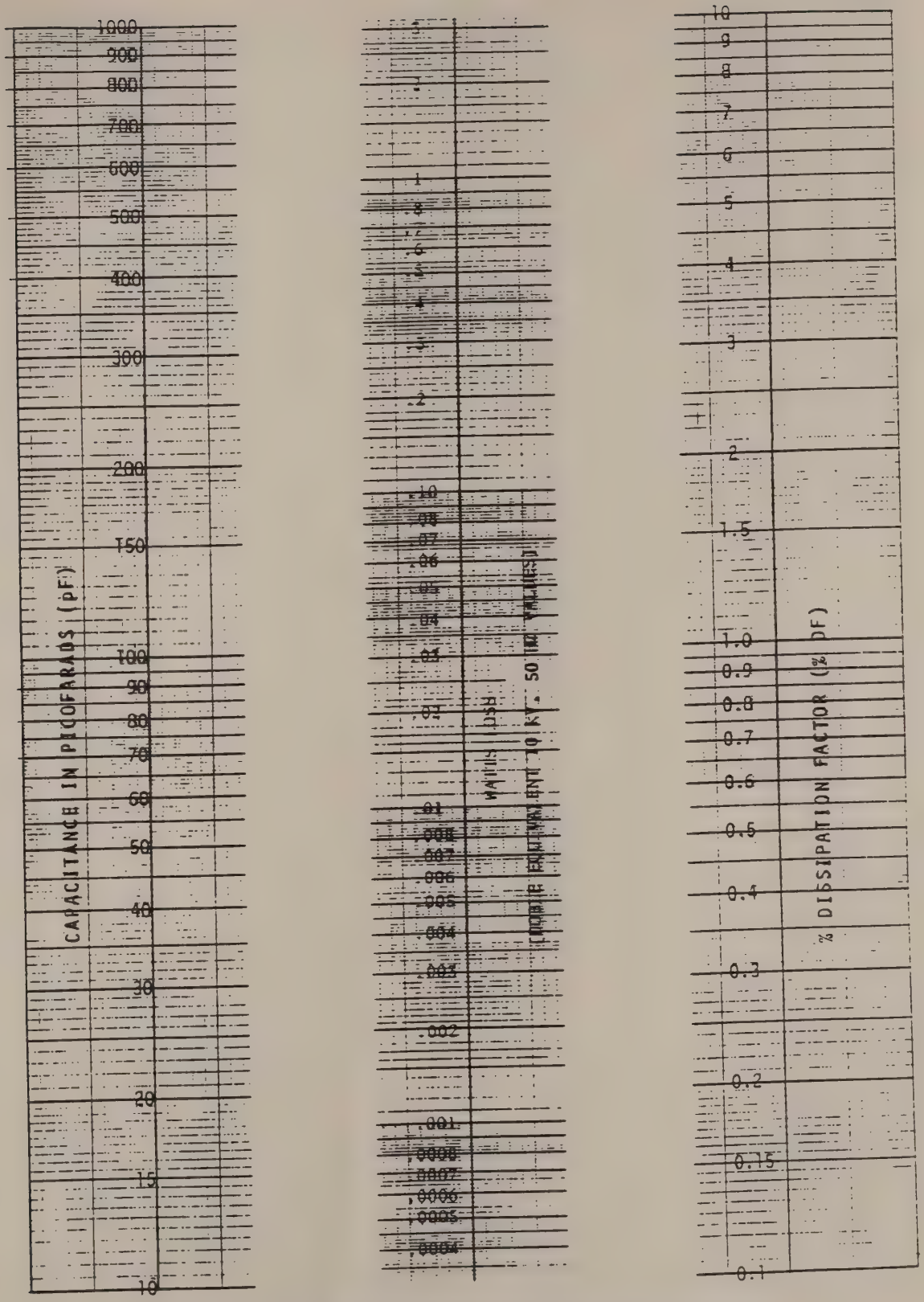


Figure 10: %DF vs. Milliwatts Loss (2.5 kV, 50 Hz)

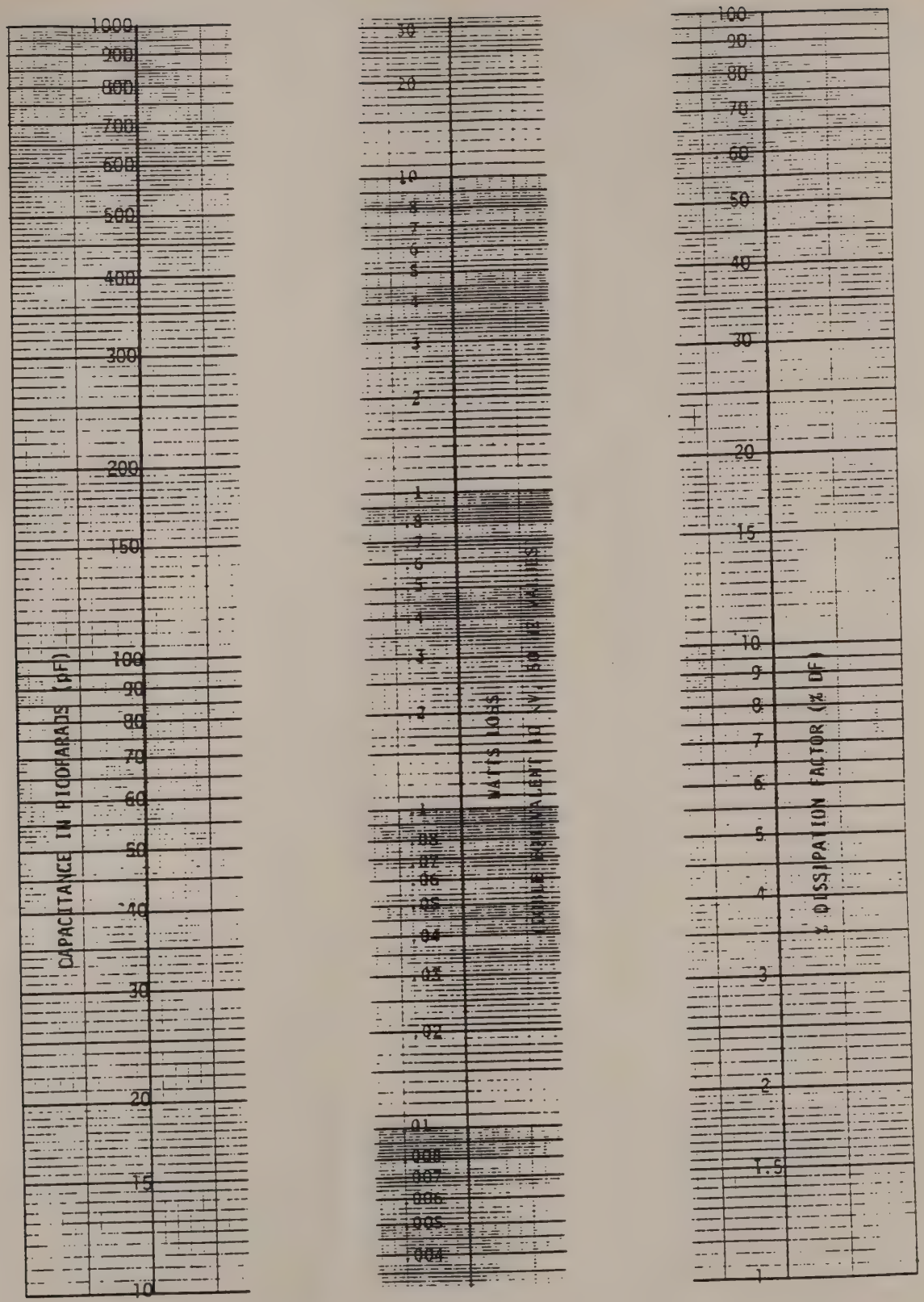


Figure 11: %DF vs. Watts Loss (10 kV, 50 Hz)

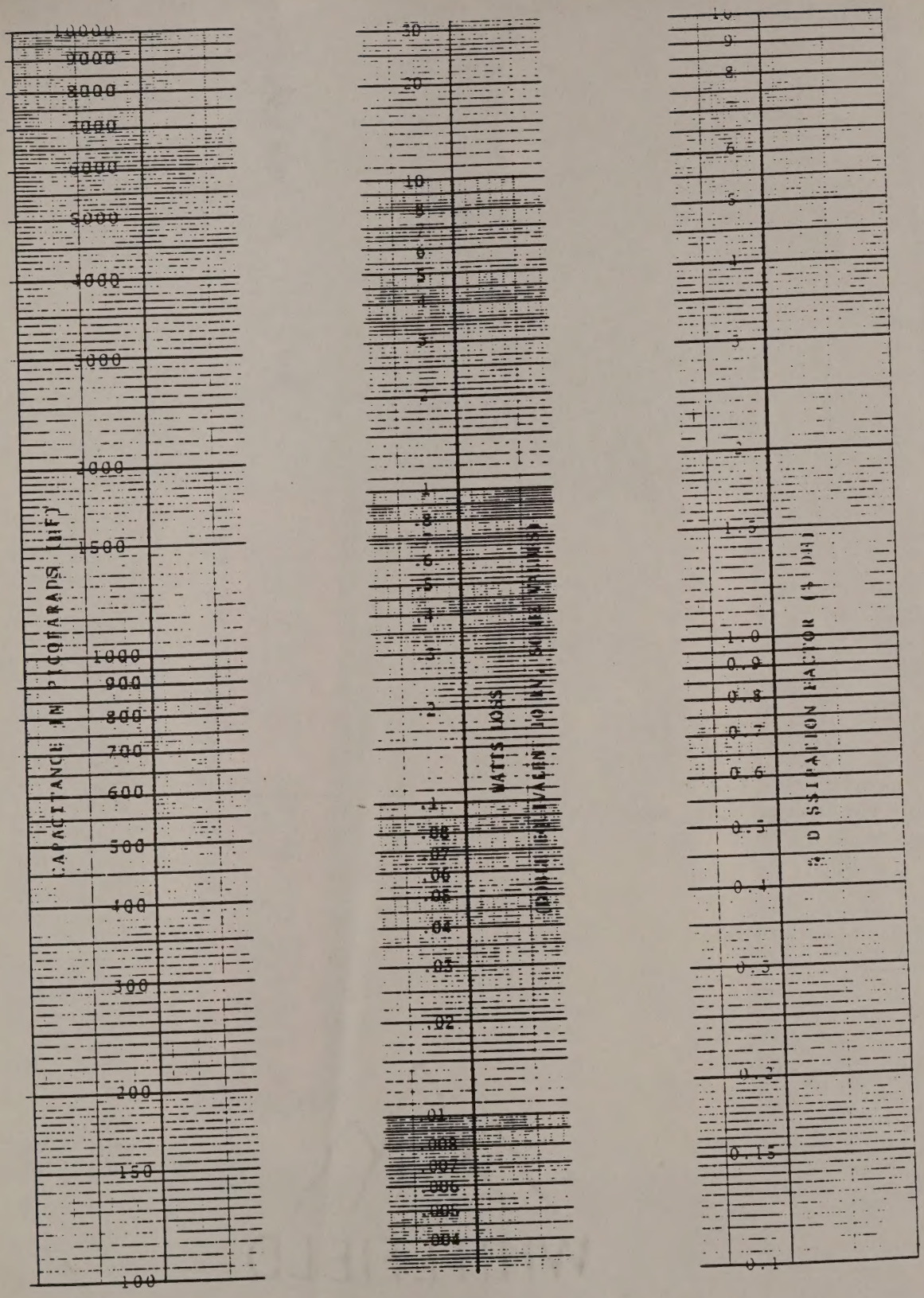
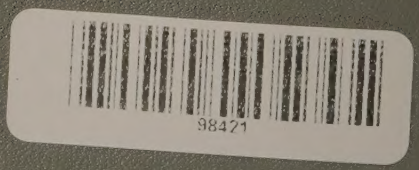


Figure 12: %DF vs. Watts Loss (10 kV, 50 Hz)

PACKING LIST ENCLOSED
PO-12


98421